Addressing Challenges and Return on Investment (ROI) for Paperless Project Delivery (e-Construction)

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FOREWORD

The Federal Highway Administration (FHWA) assessed how paperless processes were successfully used by owner agencies throughout the project delivery process. The assessment techniques included desk scans of current practices, select interviews with owner agencies, and in-depth cross-sectional analyses of practices within various project delivery phases using case studies. This work led to a deeper understanding of the specific cost and benefit categories agencies can use to conduct a return on investment (ROI) analysis for implementing e-Construction solutions within their organizations. One of the key products of the research was to develop a generalized framework, using the ROI analysis as a basis that owner agencies can use to evaluate the business case to invest in an enterprise-wide technology deployment and implementation program to standardize e-Construction practices. The research also documented challenges and lessons learned from various e-Construction implementation efforts and identified opportunities for improvement for eight specific e-Construction practices. The actionable products of the research include guidelines for assessing investment prioritization, implementing and advancing e-Constructions practices, and a benefit-cost analysis template for calculating ROI.

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16. Abstract State and local transportation departments, as well as construction contractors, are realizing the benefits of a paperless system, which include ready access to historical project documents and data, reduced printing and mailing costs, ease of updating information, simplified workflows, and quicker and more efficient project collaboration. These paperless project delivery system (e-Construction) benefits can happen before, during, and after construction of a project. The adoption of e-Construction practices has recently increased among agencies, in part due to FHWA efforts to promote this innovation during the third round of the Every Day Counts (EDC-3) initiative. However, the levels of e-Construction in project delivery vary greatly among the agencies. This study documents how state departments of transportation (DOTs) are transitioning to a more paperless project delivery system. The researchers focused on identifying the challenges encountered during implementation of e-Construction and opportunities for improvement. In addition, cost benefit data from four agencies was captured to set benchmarks used in a template to estimate return on investment (ROI) that DOTs can use to develop a business case to fund e-Construction initiatives. The actionable products of the research, which are included in this report, are guidelines for implementing e-Construction improvement opportunities and a framework for calculating ROI.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS

2D	2-dimensional
3D	3-dimensional
AASHTO	American Association of State Highway Transportation Officials
ADOT&PF	Alaska Department of Transportation and Public Facilities
AMG	Automated Machine Guidance
BCA	Benefit cost analysis
CAD	Computer Aided Drafting
CADD	Computer Aided Drafting and Design
Caltrans	California Department of Transportation
CDSv3	Construction Document System (version 3)
CMS	Contract Management System
COTS	Commercial off-the shelf
DIA	Denver International Airport
DOT	Department of Transportation
ECMS	Engineering Construction Management System
EDC	Every Day Counts
EDC-3	Round 3 of Every Day Counts
EDC-4	Round 4 of Every Day Counts
EDMS	Electronic Document Management System
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GNSS	Global Navigational Satellite Systems
iEWB	internet Extra Work Bill
iPD	integrated Project Development
IT	Information Technology
Lidar	Light Detection and Ranging
MassDOT	Massachusetts Department of Transportation

MDOT	Michigan Department of Transportation
NCDOT	North Carolina Department of Transportation
ODOT	Oregon Department of Transportation
PDF	Portable Document Format
PKI	Public Key Infrastructure
PMBOK	Project Management Body of Knowledge
PS&E	Plans, specifications, and estimates
RFP	Request for Proposal
RID	Reference Information Documents
RMP	Risk Management Plan
ROI	Return on investment
SAM	Site Access Module
TxDOT	Texas Department of Transportation
VTrans	Vermont Agency of Transportation

CHAPTER 1: INTRODUCTION

BACKGROUND

The Federal Highway Administration (FHWA)'s Every Day Counts (EDC) initiative focuses on "efficiency through technology and collaboration through a set of innovations targeted at shortening project development and delivery, enhancing roadway safety, reducing congestion, and improving environmental sustainability." (FHWA 2013a) Technical teams have developed implementation plans for each innovation and are managing the deployment effort over a two-year cycle during 2015 to 2016.

Among the innovations identified for EDC-3 is e-Construction; this initiative aims to employ established technologies readily available to the transportation community, including digital electronic signatures, electronic communication, secure file sharing, version control, mobile devices, and web-hosted data archival and retrieval systems, to improve construction documentation management. (FHWA 2013b) These improvements would allow agencies to deliver projects faster and more efficiently, thereby delivering better value for stakeholders.

RESEARCH OBJECTIVE

The primary objective of this research project is to prepare a practical guide to help agencies assess feasibility of e-Construction improvement opportunities, prioritize these opportunities, and plan for implementation. This research project responds to the increasing national interest in e-Construction implementation and in documenting the benefits and costs of using e-Construction tools.

This implementation guidance will help agencies looking to adopt e-Construction, as well as agencies that have adopted some aspects of e-Construction but are seeking to expand their programs.

E-CONSTRUCTION DEFINITION

This project follows the FHWA EDC-3 definition of e-Construction: "A paperless construction administration delivery process, including: electronic submission of all construction documentation by all stakeholders, electronic document routing and approvals (e-signature), and digital management of all construction documentation in a secure environment allowing distribution to all project stakeholders through mobile devices." (FHWA 2013b) The e-Construction process includes the following: (FHWA 2014)

- Electronic capture of construction data.
- Electronic submission of construction documentation.
- Increased use of mobile devices.
- Increased automation of document review and approval.

- Use of electronic signatures throughout the construction process by all parties involved.
- Secure document and workflow management accessible on any device.

e-Construction can be used through all steps of the project delivery process, from project advertisement to final project acceptance, including the following:

- Electronic bidding and contract award.
- Electronic plan documents.
- Project construction management (including utilization, transfer, and approval of electronic plan sets, contractor payroll submittals, claims, and change orders).
- Project inspection and data collection.
- Project acceptance (including punch lists, as-built submittal, and entering warranty phase).
- Project close-out (including retainage release and entering warranty phase).
- Project communications (e.g., public information management and internal communications).
- Resource tracking (e.g., equipment, personnel, fleet, etc.).

RESEARCH TASKS AND REPORT ORGANIZATION

The research approach undertaken to accomplish the research objectives is illustrated in Figure 1.

Figure 1. Flowchart. Research approach.

Research Current and Evolving Practice

This step involved a comprehensive literature review of information on past and ongoing efforts of agencies toward paperless or electronic project delivery, primarily in the highway construction realm. The purpose of the literature review was to better understand current effective practices for paperless delivery and identify the leading agencies that use these practices. The findings of this task are described in Chapter 2.

Document Successes, Challenges, and Opportunities

This step included three activities:

1. Analyzing results of a web-based survey administered by the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction in April 2015 (AASHTO 2015).

2. Surveying and analyzing contractor practice (WSP | Parsons Brinckherhoff 2015)

3. Conducting more detailed interviews with a subset of state transportation departments and one airport with more progressive e-Construction practices.

The survey by the AASHTO Subcommittee on Construction aimed to understand the use of e-Construction technology in project delivery with a specific emphasis on understanding the processes, tools, and systems used and the associated implementation benefits and costs. A total of 23 individuals representing 21 public agencies responded to the survey. From these responses, 10 state transportation departments and one airport were contacted to obtain further information via a structured interview. The agencies interviewed are as follows:

- Alaska Department of Transportation and Public Facilities (ADOT&PF).
- California Department of Transportation. (Caltrans).
- Denver International Airport. (DIA).
- Florida Department of Transportation (FDOT).

- Iowa Department of Transportation (Iowa DOT)
- Massachusetts Department of Transportation (MassDOT).
- Michigan Department of Transportation (MDOT).
- North Carolina Department of Transportation. (NCDOT).
- Oregon Department of Transportation (ODOT).
- Texas Department of Transportation (TxDOT).
- Vermont Agency of Transportation (VTrans).

A separate survey was administered to 24 contractors, resulting in four responses, which were analyzed to document and compare their construction practices to those of state transportation departments.

The findings from this task helped the research team gain an in-depth understanding of state transportation departments' e-Construction practices, identify any key challenges and lessons learned during implementation, identify nascent and mature practices, and isolate any documented benefit and cost data. These findings are summarized in Chapter 2.

Analyze Data and Develop an e-Construction Development Plan

This step involved identifying key areas of opportunity to develop a meaningful and progressively improving e-Construction program, developing criteria to assess feasibility based on the findings from previous tasks and the research team's prior experience and body of knowledge, and determining feasibility using the criteria. The research team also identified additional criteria that agencies can use to determine feasibility and priorities specific to their agency. The e-Construction development plan is part of the implementation guidance, which is documented in detail in Chapter 3.

Develop Implementation Guidance

This step consolidates the following elements into the implementation plan presented in Chapter 3:

- Factors for agencies to evaluate when prioritizing the focus areas of an e-Construction program.

- General guidance on benefits and costs, allowing agencies to tailor the information based on their specific processes and construction programs.

- Implementation plan guidance, including sequence of activities and strategies for overcoming common barriers for implementation.

- Recommendations for obtaining organizational buy-in and managing change.

Additionally, the guidance provides a benefit-cost analysis (BCA) tool in the form of a Microsoft Excel template to help agencies calculate return on investment (ROI) for one or multiple improvement opportunities identified in the e-Construction development plan.

Collect Benefit-Cost Data

This step involved collaboration with four state transportation departments to obtain benefit and cost information from completed e-Construction projects. These values were used to validate the planning-level estimates and are included as benchmark data in the BCA tool. This exercise was conducted in response to the lack of systematic documentation of benefits, costs, and ROI.

CHAPTER 2: STATE OF THE PRACTICE

There is an active national interest in implementing e-Construction, including electronic bidding and contract award, project collaboration tools, mobile tools, and electronic project construction management. Many agencies have begun implementing these components of e-Construction. However, a few agencies are holding off because of a lack of clarity on where to begin and the uncertainty of the cost and feasibility of implementing e-Construction. Figure 2 illustrates the state of practice findings.

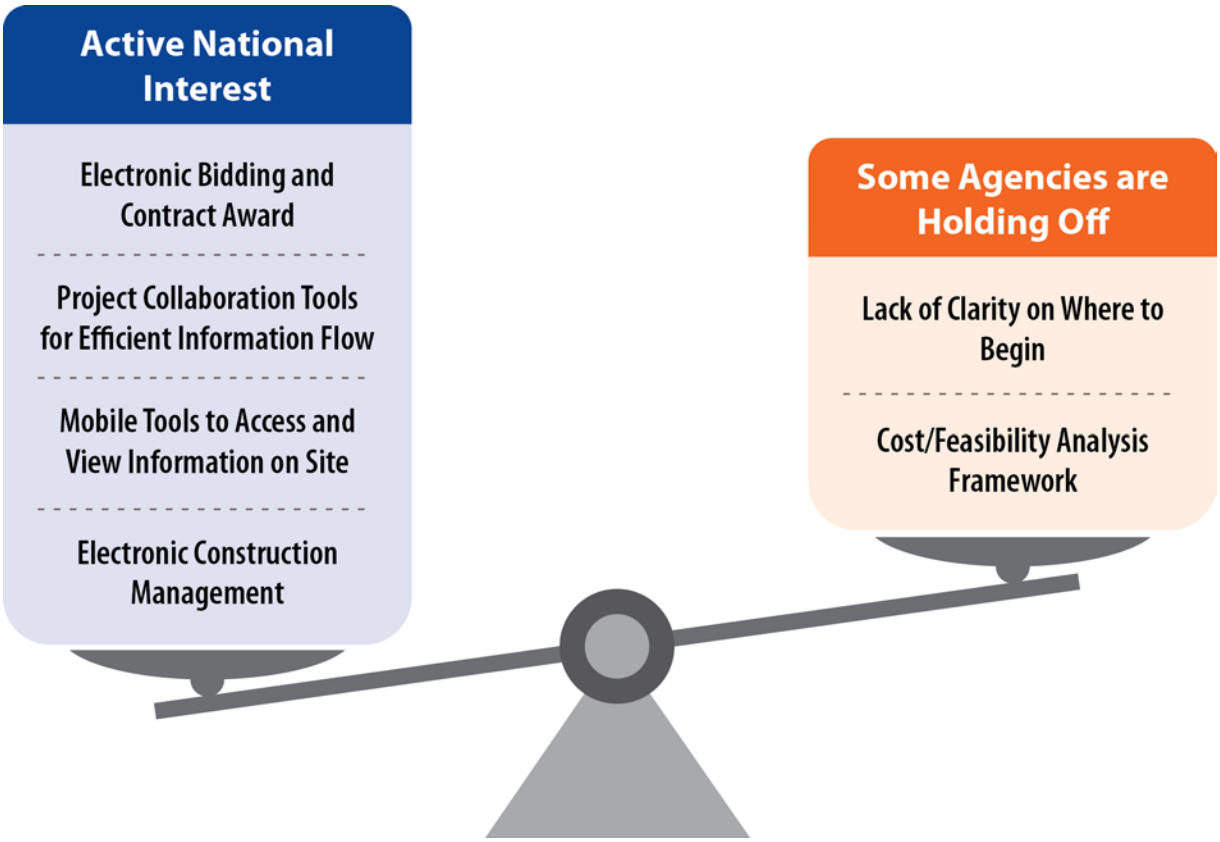

Figure 2. Illustration. Research summary findings for e-Construction state of the practice.

The state of practice of e-Construction varies widely among agencies; while some agencies are using paper documentation for most steps of the project delivery process, others are using some combination of both paper and electronic processes, and the most mature agencies are going completely paperless for the entire construction process. Michigan, for example, has moved toward becoming completely paperless and is having all state highway system projects use e-Construction (as of the 2015 construction season). The agency rates itself as 99 percent paperless—tickets for materials are still paper. Florida has replaced more than 20,000 pieces of paper by using mobile devices on four projects. In addition, Iowa is working toward becoming completely paperless for highway projects from the design phase through construction. The agency is 99 percent paperless—the last step is integrating weight tickets and scale information electronically. (FHWA 2013c)

The following sections provide a more detailed description on the state of practice of e-Construction as collected from the literature review, AASHTO survey, and interviews for each step of the project delivery process. (AASHTO 2015) (Farr 2014) (Ganley, Elmes and Jarvis 2015) (Garcia 2015) (Hoyne 2015) (McGrath 2015) (Mulder 2015) (Nagel and Usher 2015) (Rice and Rivas 2015) (Squire 2015) (Sylvester and Johnson 2015) (Tootle and Martin 2015) (Vandeventer 2015) These steps include:

1. Transfer/Sharing of Plans, Specifications, & Estimates (PS&E), which includes:
    a. Plans and specification documents in Computer Aided Design and Drafting (CADD) or Personal Document Format (PDF).
    b. Tie-in of three-dimensional (3D) plans to automated machine guidance (AMG) equipment.
    c. Digital sealing and stamping of plan sets.
2. Electronic Bidding and Contract Award, which includes:
    a. Electronic bidding through automated software.
    b. Digital signatures.
3. Project Construction Management, which includes:
    a. Electronic review and approval process (digital signatures/reviews).
    b. Collaborative sharing sites.
    c. Material testing and quality assurance records (including quality control, independent verification, inspection, and acceptance testing).
    d. Contractor payroll submittals.
    e. Digital signatures.
    f. Claims and change orders.
    g. Mobile technologies for data collection.
4. Project Inspection and Testing, which includes:
    a. Mobile technologies for data collection.
    b. Tracking of inspection activities and material testing results.
    c. Survey instruments.
5. Project Acceptance, which includes:

a. Providing documentation (e.g., punch lists, as-builts submittal, and entering warranty phase) in the form of CADD or PDF files.

6. Project Close-Out, which includes:

   b. Tracking of warranty items.

   c. Payment release.

7. Data Sharing between steps/phases, which includes:

   a. Seamless integration across all e-Construction systems/tools.

   b. Electronic transfer of data between systems (e.g., contractor payment approvals to financial and accounting systems).

For a summary of key agency practices for each project delivery step, as identified through the AASHTO survey, the contractor survey, and agency interviews, refer to Appendix A.

PLANS, SPECIFICATIONS, AND ESTIMATES (PS&E)

Many agencies use electronic files in CADD software format for creating plan sets. A common practice is to then deliver these plans as two-dimensional (2D) CADD files or PDFs. The use of 3D models as reference information documents (RID) is still an emerging practice, although many states have a mature practice of delivering 3D models as RID, including Iowa , Connecticut, Florida, Michigan, Missouri, New York, Oregon, Utah, West Virginia, and Wisconsin (FHWA 2016). Utah recently completed a project in which the 3D model was the contractual document for the bid letting. (Wheeler and Wood 2016) For the digital review of plan sets, more agencies are transitioning from a paper process to review plans (i.e., marking up and then scanning those plans) to using a software to mark-up plans.

ELECTRONIC BIDDING AND CONTRACTOR SELECTION

Electronic bidding is the most mature practice among state transportation departments for several reasons: it has had a longer lead time to mature and take hold, several commercial-off-the shelf (COTS) solutions are available on the market, it is relatively quick to implement, and agencies quickly realize benefits. The common tool identified for electronic bidding was Bid Express along with Expedite as the companion program to prepare and submit the electronic bid. Other solutions identified were ExeVision's integrated Project Development (iPD) solution. Many states also require contractors to submit their bids electronically for all projects (e.g., California, Iowa, Kentucky, Michigan, Minnesota, and Vermont). However, other states require electronic bidding only for projects over certain contract value (e.g., Florida requires electronic bids for projects over $5 million). Texas stated that although electronic bidding is currently voluntary, about 90 and 95 percent of contractors bid electronically for maintenance and construction projects, respectively.

Alaska, New Hampshire, and the Denver International Airport reported that they still use paper bidding. Alaska, however, is looking to transition to an electronic bidding solution.

The contractors surveyed most frequently use electronic bidding, which aligns with the practices of state transportation departments. (WSP | Parsons Brinckherhoff 2015)

PROJECT CONSTRUCTION MANAGEMENT

Agencies either use a combination of paper and semi-electronic systems or electronic construction management systems. A completely paper-based process to manage construction progress is rarely used, likely because is labor and resource intensive. During this step of this project delivery process, agencies use a variety of systems and tools, including electronic construction management to manage construction progress, a collaboration tool to share project documentation, and digital signatures to enable staff to authenticate documents electronically, which is also used for the stamping of plan sets and during electronic bidding.

Construction Management Systems

Most states use a COTS solution for their construction management systems (e.g., AASHTOWare products), although some states use custom-developed solutions, such as North Dakota, New Hampshire, and Pennsylvania).

Project Collaboration Tools

Most agencies use COTS software for project collaboration. Common tools include ProjectSolve, ProjectWise, SharePoint, and DocExpress. (FHWA 2013c) A project collaboration tool enables all project documentation to be stored in one place so that staff can easily access the documents they need in a timely manner. In addition, collaboration tools facilitate communication and collaboration since staff can work on the same set of documents and easily pass documents back and forth. A project collaboration tool typically stores documentation for the life of the project, after which it is migrated to the agency's enterprise document/content management system for archiving.

Digital Signatures

More agencies are transitioning to digital signatures because it streamlines the approvals process, thereby enabling faster approvals and change orders. Digital signatures can be implemented at a relatively low cost to the agency because any fees associated with the process are transferred to the contractor. However, a key challenge that agencies have to overcome is implementing a policy that will allow the use and acceptance of digital signatures. Many state laws already allow the use of digital signatures for e-commerce, and its acceptance has become quite prevalent in the last decade. In addition to the Project Construction Management project delivery step, digital signatures are being used for the preparation of plan sets (digital stamping and sealing) and electronic bidding.

The contractors surveyed also use either a combination of paper and semi-electronic systems or electronic construction management systems, which align with the practices of state transportation departments. (WSP | Parsons Brinckherhoff 2015)

PROJECT INSPECTION AND TESTING

The majority of state transportation departments use a combination of manual and electronic systems and tools for project inspection and testing. Mobile devices are most commonly used, although some agencies still use laptops. Agencies use mobile devices not only to enter and track inspection data, but also to record field activities in the construction management system, to access plan sets and manuals, and to communicate with office staff. Mobile devices enable easier access to real-time information and more accurate data collection in the field. They also give inspectors access to a vast range of applications that can help them in the field; the applications that are used are ultimately contingent on user preference. For example, Texas encourages inspectors to explore free applications on the iPad. The agency had user groups test out different applications and report on their findings.

Many agencies use ad-hoc approaches to procure and use mobile devices, which can result in short-term solutions but create issues over the longer term regarding duplicate devices and services, as well as multiple locations and methods to store all data and information. As a result, mobile devices should be used in conjunction with other electronic systems as an extension of those systems to obtain the most benefits.

The contractors surveyed rarely use manual, paper-based systems for project inspection and testing, which aligns with the practices of state transportation departments. (WSP | Parsons Brinckherhoff 2015)

PROJECT ACCEPTANCE

The majority of agencies are being provided as-built documentation in the form of PDFs or computer aided drafting (CAD) files. The provision of 3D as-built models for project acceptance is uncommon, although this is the direction that the industry is moving in. The Project Acceptance process is typically a combination of a manual and electronic process since manual checks have to be conducted before a project is accepted by an agency.

The majority of contractors surveyed provide either paper or CADD as-built documentation to the owner, which aligns with the practices of state transportation departments.

PROJECT CLOSE-OUT

Most agencies use a combination of electronic and paper practices for project close-out, and the practice of tracking warranty items varies. Some agencies use a manual process, while others use a combination of manual and automated tracking. A few states use an automated tracking process (e.g., Florida, Pennsylvania, and Vermont).

DATA SHARING BETWEEN STEPS/PHASES AND INTEGRATION ACROSS ALL E-CONSTRUCTION OPPORTUNITIES

While many agencies have made significant strides in implementing an e-Construction program, there has not yet been a focus on integrating the various components of e-Construction (e.g., digital signatures and electronic bidding) in order to maximize the benefits for their investment.

However, there is some level of data sharing between the construction management and the financial or accounting systems.

Integrating digital data across all e-Construction processes will ultimately help agencies streamline the project delivery process and result in additional efficiencies that will increase benefits significantly.

SUMMARY OF STATE AGENCY MATURITY

A summary of agency practices, as identified through the literature review, the findings from the AASHTO survey, and detailed interviews, are presented in Table 1 through Table 7 using a maturity framework to show where agencies fit on a scale ranging from nascent to mature. This information is current as of spring 2015 when the survey was administered and the interviews were conducted. Appropriate annotations regarding what the scale means for each category are also provided in the tables.

Table 1. Summary of state of the practice for PS&E.

LEVEL 1: NASCENT Paper PS&E packet that may be scanned, and paper plan review	**LEVEL 2: INTERMEDIATE** Electronic files in CADD software format and electronic plan review	**LEVEL 3: MATURE** 3D plans (geospatial) that allow quantity take-offs, tie-in to AMG equipment
• Alabama • Alaska • Arkansas • Colorado • New Hampshire • Ohio • Pennsylvania • Virginia • Washington	• California • Connecticut • Florida • Kansas • Kentucky • Louisiana • Massachusetts • Michigan • Minnesota • Nebraska • New Jersey • North Carolina • North Dakota • Vermont • West Virginia	• Iowa, • Oregon • Texas

Table 2. Summary of the state of the practice for electronic bidding and contract award.

LEVEL 1: NASCENT Paper bidding and selection	LEVEL 2: INTERMEDIATE Online bidding as well as offline/paper bids	LEVEL 3: MATURE Mandatory electronic bidding through Bid Express or other automated software, including electronic signatures
• Alaska • New Hampshire	• Alabama • Florida • Minnesota • Nebraska • North Carolina • Oregon • Texas	• Arkansas • California • Colorado • Connecticut • Florida • Iowa • Kansas • Kentucky • Louisiana • Massachusetts • Michigan • Minnesota • Missouri • New Jersey • North Dakota • Ohio • Pennsylvania • Tennessee • Utah • Vermont • Virginia • Washington • West Virginia

Table 3. Summary of the state of the practice for project construction management.

LEVEL 1: NASCENT Paper documentation (contractor and owner)	LEVEL 2: INTERMEDIATE Combination of paper and semi-electronic systems (e.g., Microsoft Word) to track daily reports stored on a computer	LEVEL 3: MATURE Electronic construction management systems (e.g., SiteManager) to track daily reports, progress percentage, change orders, payments, and other information
• None identified	• Alabama • Alaska • California • Connecticut • Florida • Iowa • Kansas • Louisiana • North Dakota • Oregon • Utah • Washington • Wisconsin	• Arkansas • Colorado • Connecticut • Florida • Iowa • Kentucky • Michigan • Nebraska • New Hampshire • North Carolina • Ohio • Pennsylvania • Texas • Vermont • Virginia • West Virginia

Table 4. Summary of the state of the practice for project inspection and testing.

LEVEL 1: NASCENT Manual, paper-based methods and use of analog tools (e.g., straight edges and measuring wheels)	LEVEL 2: INTERMEDIATE Mix of manual and electronic systems (e.g., SiteManager) to track inspections and material test results	LEVEL 3: MATURE Electronic systems (e.g., SiteManager) to track all inspections and materials test results. Capability to geo-code data (e.g., indicate location of test cores). Survey instruments to check tolerance against design (geospatial rovers) – pay plan quantities
• California • Massachusetts • Oregon	• Alabama • Alaska • Arkansas • Colorado • Connecticut • Florida • Iowa • Kansas • Louisiana • Nebraska • New Hampshire • Nevada • North Carolina • North Dakota • Ohio • Texas • Vermont • Virginia • West Virginia • Washington • Wisconsin	• Michigan • Pennsylvania

Table 5. Summary of the state of the practice for project acceptance.

LEVEL 1: NASCENT Paper as-built documentation provided to owner	LEVEL 2: INTERMEDIATE CADD files provided to owner	LEVEL 3: MATURE 3D as-built models provided to owner
• Alabama • Alaska • Arkansas • Florida • Massachusetts • Nebraska • New Hampshire • North Carolina • North Dakota • Oregon • Pennsylvania • Vermont • Virginia • Washington	• California • Connecticut • Iowa • Louisiana • Kansas • Ohio • Washington • West Virginia • Wisconsin	• Michigan

Table 6. Summary of the state of the practice for project close-out.

LEVEL 1: NASCENT Manual tracking of most warranty items	LEVEL 2: INTERMEDIATE Some automated tracking of warranty items through spreadsheets	LEVEL 3: MATURE Release retainage amount to contractor automatically, ability to show all project warranty items and details on a map
• Alabama • Alaska • California • Connecticut • New Hampshire • Oregon • Virginia	• Arkansas • Iowa • Kansas • Louisiana • Massachusetts • Michigan • Nebraska • North Carolina • Pennsylvania • West Virginia	• Florida

Table 7. Summary of the state of the practice for data sharing between steps/phases.

LEVEL 1: NASCENT Mostly paper systems, no data sharing between systems	LEVEL 2: INTERMEDIATE Stand-alone electronic systems, including spreadsheets and other electronic records	LEVEL 3: MATURE Electronic transfer of data between steps/phases, eliminating duplication; ability to share data electronically between systems (e.g., contractor payment approvals to financial and accounting systems); use of Civil Integrated Management practices
• Louisiana • Massachusetts • Oregon	• Connecticut • Iowa • Kentucky • Nebraska • New Hampshire • North Dakota • Texas • Vermont	• Alabama • Arkansas • Colorado • Florida • Kansas • Michigan • North Carolina • Ohio • Pennsylvania • Virginia • Washington • West Virginia

COMMON TOOLS USED FOR E-CONSTRUCTION

Table 8 through Table 11 provide an overview of the common types of applications, services, and software used for e-Construction and the applicable key project elements. This list is not all inclusive, but it represents the majority of applications available in the market and being used by many state transportation departments. Many of these technologies are not specific to the construction industry but are rather broader collaboration tools used across an array of other industries.

Table 8. e-Construction commonly used tools for plan set review and preparation[1].

Application/Service/Software	Description	Project Elements
Adobe Acrobat products	PDF solution for creating, editing, and managing documents; used for plan set review and signing and sealing plan sets	PS&E
Autodesk AutoCAD and Civil 3D, Bentley MicroStation, Geopak, InRoads, and MX	CAD software for 2D and 3D design	PS&E
Bluebeam Revu	Software used to edit and markup digital plans collaboratively	Construction Management and Project Acceptance

Table 9. e-Construction commonly used tools for electronic bidding and contract award[1].

Application/Service/Software	Description	Project Elements
Bid Express	Internet bidding service that enables an agency and contractors to communicate with each other; it is used to submit the bid, view and download project information, and access plans and bid data online; this service is often used in conjunction with the Expedite Bid software	Bid Advertisement, Electronic Bidding and Contract Award
Expedite Bidding Software	Software used to prepare, validate, and analyze an electronic bid and is often used in conjunction with the Bid Express service	Bid Preparation, Electronic Bidding and Contract Award
DocuSign	Digital signature product to securely access and sign documents to complete approvals and agreements	Electronic Bidding and Contract Award, and Construction Administration

[1] These are the products shared during the interviews, and may not be all inclusive.

Table 10. e-Construction commonly used tools for project collaboration[1].

Application/Service/Software	Description	Project Elements
Doc Express	Paperless contracting service that enables document exchange during construction projects; also allows for electronic signatures	PS&E, and Construction Management
OnBase	Enterprise information platform for managing content, processes, and documents, including CAD drawings	PS&E, Construction Management, and Post-Construction
ProjectSolve	Internet-based collaboration tool that allows project teams to communicate and collaborate with each other	Construction Management
ProjectWise	Suite of software used for information management to manage, share, and distribute project materials in a single platform	PS&E and Construction Management
SharePoint	Internet-based collaboration tool that allows project teams to communicate and collaborate with each other	Construction Management

Table 11. e-Construction commonly used tools for project construction management and mobile devices[1].

Application/Service/Software	Description	Project Elements
AASHTOWare Project	Enterprise software suite that includes modules used to manage contract administration, contract records, daily work reports, contractor payments, materials management, and laboratory inventory management. The most commonly used modules are SiteManager and FieldManager	Project Construction Management
Mobile Inspector by Infotech	Mobile application used to enter daily activities. This product is compatible with AASHTOWare Project	Project Construction Management
Headlight by Pavia Systems	A cloud-based application used to enter daily inspector diaries in the field in real-time. Application also has a desktop client	Construction Inspection and Testing
Masterworks by Aurigo	Cloud-based application used to document daily activities and Laboratory Inventory and Materials information. It has a mobile and desktop client	Construction Inspection and Testing
Primavera P6	Project management software to assist with planning, scheduling, and controlling project resources	Project Construction Management
Android tablet, Apple iPads, Windows tablets	Mobile devices enabling inspectors to collect data, access documents and applications from the field, and collaborate with office staff	Project Construction Management

CHAPTER 3: IMPLEMENTATION GUIDANCE

The how-to guide herein is provided to state transportation departments looking to implement the e-Construction improvement opportunities identified and defined in this section. These eight improvement opportunities collectively represent the key components to developing a comprehensive e-Construction program that will improve the project delivery process and help agencies realize efficiencies and cost savings. These opportunities were identified based on a literature review of existing e-Construction documentation, the AASHTO survey, and detailed interviews conducted with state transportation departments. (AASHTO 2015) (Farr 2014) (Ganley, Elmes and Jarvis 2015) (Garcia 2015) (Hoyne 2015) (McGrath 2015) (Mulder 2015) (Nagel and Usher 2015) (Rice and Rivas 2015) (Squire 2015) (Sylvester and Johnson 2015) (Tootle and Martin 2015) (Vandeventer 2015)

WHO SHOULD USE THIS GUIDANCE?

The audience for this e-Construction implementation guidance includes staff members analyzing the feasibility of various e-Construction improvement opportunities, decision makers, and end users of the project delivery processes and tools. These staff members reside in many functional areas, including construction, design, planning, and Information Technology (IT). Thus, proper coordination and collaboration is highly recommended.

E-CONSTRUCTION IMPROVEMENT OPPORTUNITIES

Pre-construction

Electronic Bidding and Contract Award

This improvement opportunity includes bid preparation, submittal, acceptance, evaluation, and contract award through an electronic system. Electronic bidding and contract award is among the most mature of e-Construction practices; nevertheless, many state transportation departments are not maximizing the full benefits of this digital process. In many cases, the processes for preparing and evaluating bids are still manual. The primary benefits are quicker and more accurate bids due to electronic/automated checking of formulas and real-time submittal, and the reduction of carbon footprint.

Digital Plans, Specifications, and Estimates

This improvement opportunity refers to the preparation of digital and intelligent PS&E documents during the pre-construction phase, including electronic specifications and estimates, and 2D or 3D digital plan sheets as PDFs generated directly from CADD software. Additionally, it includes the use of these digital intelligent documents to review, collaborate, and approve the bid package during design and advertisement. Lastly, digital PS&E documents may include issuing 3D engineered models as contractual documents during advertisement. 3D design data enables the use of quantity take-offs during bidding, the use of AMG construction methods, and quantity verification and measurements during construction. Digital PS&E documents enable other paperless processes, such as electronic bidding and digital project review. The primary benefits are improved efficiencies due to turn-around time to receive comments during the

design phase. The costs and benefits listed in the analysis focus on pre-construction activities only.

Construction

Digital Review of Contract Documents

This improvement opportunity includes the review and approval of contract documents once an award has been made. The awarded contractor submits all required contractual documents via a secure electronic system for the agency to review, accept, and execute the contract before construction begins. The primary benefits are improved efficiencies and faster turn-around times during the transmittal and approval of documents. Digital review combined with mobile devices can allow staff to both access and review information faster.

Project Construction Management

This improvement opportunity refers to the use of an electronic system that handles contract administration, payroll and contractor payments review, documentation of project data and records, change order approvals, project reporting, tracking of materials and daily field activities, integration of material and lab administration, and project close-out. A construction management system allows members of the project to both enter and retrieve information faster and more efficiently compared to a paper-based process.

Digital Management of Construction Documentation using a Project Collaboration Tool

This improvement opportunity includes the use of a document management system for sharing documents and collaboration during the construction of a project by all parties involved. The primary benefits are improved documentation and transparency, and increased efficiencies and accessibility.

Post-construction

Requirement of Digital As-Built Records

This improvement opportunity refers to the requirement for providing digital as-builts in the form of 3D CADD and Geographic Information System (GIS) data collected using geospatial technologies (e.g., Global Navigational Satellite Systems (GNSS) equipment, light detection and ranging (lidar[2]), and unmanned aircraft systems) at the time of project acceptance. The primary benefits are more accurate records that augment a programmatic asset inventory database and accessibility to information for asset maintenance and operation.

[2] Note that lidar is sometimes referred to as LiDAR, LIDAR, LADAR, or laser scanning, which mostly refer to the same technology. The format lidar is adopted in this report since it is the predominant convention used in the industry.

Cross-cutting opportunities[3]

Digital Signatures

This improvement opportunity includes the use of digital signatures for authenticating and approving documents electronically across all phases of the project delivery cycle. Digital signatures are a dependency for multiple improvement opportunities identified herein, such as accepting electronic bids, signing digital PS&E documents, managing construction documents digitally (e.g., change orders and approvals), and acceptance of digital as-builts.

Mobile Devices

This improvement opportunity includes the use of mobile devices to assist in both collecting and retrieving various data electronically in the field. As with digital signatures, mobile devices are used in combination with other improvement opportunities identified herein (e.g., digital access of PS&E documents, reference materials, and construction management systems). The primary benefits are increased transparency, accessibility, mobility, and communication.

HOW TO USE THIS GUIDANCE?

This implementation guide is intended to be a general reference based on the three basic steps illustrated in Figure 3.

Figure 3. Flowchart. Steps to follow as general guidance for implementing e-Construction.

The implementation guide is organized as follows:

1. **Initial Self-Assessment.** The self-assessment tool enables agencies to assess their e-Construction maturity relative to industry best practice. The matrix is organized by each improvement opportunity and consists of a three-point maturity scale for agencies to assess their current practices.

2. **Prioritizing Improvement Opportunities and Developing a Business Case**

    a. **Prioritizing Improvement Opportunities**. Once agencies assess their maturity, the next step is to determine which improvement opportunities agencies already use and which

[3] Cross-cutting improvement opportunities are used across multiple project delivery phases and are considered a dependency for implementing e-Construction technologies.

they should implement next, guided by a set of prioritization criteria. These criteria will help agencies determine the feasibility and priority of the various improvement opportunities in order to map out a path for moving forward with their e-Construction programs.

b. **Estimating Quantitative Benefits and Costs.** This section presents a framework for estimating benefits and costs for the improvement opportunities identified in the prior step and includes a set of planning-level estimates over a seven-year planning horizon for each improvement opportunity. This information allows agencies to prepare a ROI, which is a key metric for decision makers.

3. **Project Success Factors.** This section focuses on the considerations for successful project implementation. Subsections include:

   a. **Risk Management.** This section describes the typical barriers to implementation, along with strategies to respond to and mitigate each risk. The research team follows the Project Management Institute's PMBOK® Guide definition of risk, which is defined as "an uncertain event or condition that, if it occurs, will have a negative or positive effect on one or more project objectives." (Project Management Institute 2013)

   b. **Change Management.** Early and ongoing involvement and input throughout the implementation process are essential to developing a tool that truly meets the needs of the agency, to gaining user acceptance and, ultimately, to achieving a successful project.

   c. Other Success Factors. This section describes other key success factors to help agencies organize their approach to implement new technologies and practices. These include factors such as business process improvement, project sponsorship, tool selection to meet the agency's needs, and training.

INITIAL SELF-ASSESSMENT

The first step to complete when defining an implementation plan is to accurately assess the current practices within the organization. It is highly recommended to make an assessment for each improvement opportunity previously defined using the initial self-assessment tool presented in Table 12 through Table 15. This tool compares the agency maturity level to industry best practices. The self-assessment enables agencies to understand their maturity baseline and use the scale to guide their adoption of e-Construction improvement opportunities over the next few years. It is important to note that once the baseline is established, the desired target goal should be also identified. Given the broad spectrum of e-Construction practices, it is possible that an agency may be advanced in some processes, while nascent or intermediate in others.

The self-assessment tool defines three levels of maturity for each improvement opportunity:

1. Nascent: Mostly paper-based process.

2. Intermediate: Combination of paper and electronic processes.

3. Advanced: Electronic process.

Table 12. Level of maturity matrix for e-Construction improvement opportunities (pre-construction).

Improvement Opportunities	Nascent	Intermediate	Advanced
Electronic bidding and contract award	Paper-based bidding and contract execution	Optional electronic bidding; paper-based and electronic advertisement	Mandatory electronic bidding; electronic advertisement only
Digital PS&E	Paper plans or PDF plans (scanned)	Electronically signed and sealed contract plans; 3D models shared as reference information (non-contractual)	3D models provided as contractual documents

Table 13. Level of maturity matrix for e-Construction improvement opportunities (construction).

Improvement Opportunities	Nascent	Intermediate	Advanced
Digital review of project documents	All reference materials and plans are paper documents	Mix of electronic and paper reference materials and plans	All reference materials and plans are available electronically (e.g., specifications, standard drawings, contract, forms, etc.)
Project construction management	Paper-based contract management	A mix of paper-based and electronic contract management using tools such as Microsoft Word (e.g., to track daily reports stored on a computer), spreadsheets, and independent databases	Enterprise-level project construction management system that can be accessed in the office using a desktop computer and in the field with mobile devices; provides real-time information
Digital management of construction documentation using a project collaboration tool	Paper-based processes with no automated way to share documents	Internal project collaboration tool (inside the agency's firewall only); electronic mail communication	Enterprise project collaboration tool that can be accessed inside and outside of the firewall securely
AMG for construction operations	AMG construction is not allowed on construction projects	AMG construction is allowed and the agency does not have specifications for contractors; nor guidelines or training for inspectors	AMG is allowed and the agency has specifications for contractors; guidelines and training available for inspectors

Table 14. Level of maturity matrix for e-Construction improvement opportunities (post-construction).

Improvement Opportunities	Nascent	Intermediate	Advanced
Digital as-built records	Paper-plans are redlined and archived in drawers/boxes	PDF plans are redlined and electronically indexed and archived	3D digital as-built records are required as a final product for both subsurface utilities and above-ground features; electronic punch-lists and alerts are used for closing projects

Table 15. Level of maturity matrix for e-Construction improvement opportunities (cross-cutting/dependencies).

Improvement Opportunities	Nascent	Intermediate	Advanced
Digital signatures	Use of ink signatures and seals	A mix of ink and digital signatures/seals depending on the project delivery step	Digital signatures replace all ink signatures and seals
Mobile devices	All paper-based processes	Mobile devices available for certain types of projects	Mobile devices are standard tools used for inspection of all projects

PRIORITIZING IMPROVEMENT OPPORTUNITIES AND ESTIMATING BENEFITS AND COSTS

Prioritization Criteria for Improvement Opportunities

Once agencies have assessed their current e-Construction capability, the next step is to use a set of prioritization criteria to determine the feasibility and priority of implementing each e-Construction improvement opportunity, as previously identified. The prioritization criteria were developed based on research findings and current state-of-the-practice. The criteria are divided into the following categories:

- **Benefits to the agency.** Evaluates whether and how the electronic system/tool will provide benefits to the agency.

- **Likelihood of success.** Considers the factors that will contribute to the agency's likelihood of successful implementation, such as maturity of the practice, successful implementation by other agencies, availability of strong COTS solutions, and policies to support the use of the system/tool.

- **Level of complexity.** Assesses the current paper-based process, how an electronic system will simplify it, and the complexity of the technology deployment to implement a digital solution.

- **Leverage existing resources.** Considers whether the agency can leverage existing processes and resources to facilitate implementation of the improvement opportunity.

The research team used the criteria identified in Table 16 through Table 23 to evaluate the feasibility for each improvement opportunity. The evaluation criteria include questions with "Yes" and "No" answers that help with the overall assessment for implementing each improvement opportunity. In some cases, the criterion was "maybe," or "it varies." A detailed assessment of each improvement opportunity is provided in Appendix B.

Table 16. Prioritization criteria for evaluating benefits to the agency.

Prioritization Criteria	Evaluation Key
Will this improvement opportunity improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, this improvement will help improve the streamlining of processes, increase consistency, and improve efficiency and turn-around times for approvals, which translate into tangible benefits. **No**, the processes are simple or streamlined, and adding electronic systems will not improve turn-around times for approvals that result in significant benefits.
Will this improvement opportunity improve workforce utilization?	**Yes**, the improvement will allow staff to conduct activities faster and eliminate or simplify certain steps that are time consuming and cumbersome resulting in additional capacity to work on other tasks. **No**, the improvement would not change staff efficiency or allow for faster work completion.
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, this improvement will allow the staff to receive and review project-related information and approve requests for changes and work orders faster, which will result in quicker turn-around times to start physical work. This acceleration of construction management tasks reduces the timeline for the overall project schedule. **No**, this system/tool by itself may not impact the time it takes to review and approve information related to the project. It may, in conjunction with other systems and tools, provide benefits and efficiencies that will contribute to faster turn-around times.
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, this improvement will reduce risk to the agency and/or the contractor. **No**, this improvement may not directly reduce risk but could reduce risks when used in conjunction with other systems and tools.

Table 17. Prioritization criteria for evaluating likelihood of success.

Prioritization Criteria	Evaluation Key
Have other agencies implemented this improvement? Have they documented the benefits, costs, and lessons learned?	**Yes**, agencies can benefit from the experience and lessons learned (including how challenges were overcome) of other agencies that implemented the improvement, which can significantly increase the likelihood of success. **No**, the improvement has not been implemented widely; therefore, agencies do not have the benefit of lessons learned and peer exchanges.
Is there a strong COTS solution that can lead to this improvement?	**Yes**, a strong COTS solution exists to implement this improvement, meaning there is expertise in the marketplace to help with the implementation and that other agencies may have implemented this improvement. **No**, without a strong COTS solution, agencies may have to either custom develop or heavily customize a COTS, which could result in higher costs and no industry expertise (outside the agency) to support the implementation.
Are there existing state or federal requirements, statutes, or policies to support the improvement?	**Yes**, state or federal requirements, statutes, or policies are in place (e.g., the use of digital signatures is permitted), which means there will be no major legal or statutory hurdles for implementing the improvement opportunity. **No**, the improvement would require changes to existing policies or statutes. This may result in a longer implementation time frame and additional work to change policies or statutes.

Table 18. Prioritization criteria for evaluating level of complexity.

Evaluation Key	Prioritization Criteria
What is the simplicity/complexity of current process?	A complex business process offers more opportunities for standardization and consistency by making the steps electronic, more streamlined, and consistent. However, a complex technology process may make it more difficult to implement a solution in a short amount of time. A simple business process may not offer the same level of opportunities for standardization/consistency. On the contrary, a simple technology process may offer the quickest implementation solution to improve turn-around times for completing certain tasks.
Will the current paper-based process be simplified? If so, how much?	**Yes**, implementing the opportunity would help streamline and simplify the process. **No**, implementing the opportunity would not help streamline or simplify the process.

Table 19. Prioritization criteria for evaluating how to leverage existing resources.

Prioritization Criteria	Evaluation Key
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, leveraging existing systems/tools can help agencies make the most of their resources, and creating synergies with existing processes can help maximize benefits/cost savings. **No**, there are no documented cases for integrating this process with the agency's existing systems/tools. The agency may have a custom-developed solution that may make integration with a COTS solution difficult.
Are there documents or forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, documents or forms that can be easily converted to or originate in an electronic format will help facilitate the implementation process. **No**, documents or forms cannot easily be converted to the desired electronic format (e.g., making the switch from PDF plan sheets to digital as-built records) and will require additional effort during the development/ implementation process.

Additional Prioritization Criteria

Table 20 through Table 24 list additional considerations that may vary significantly for each agency and thus cannot be generalized. Nevertheless, these questions should be considered to completely assess the feasibility and determine the prioritization of e-Construction improvement opportunities.

Table 20. Additional prioritization criteria to assess overall agency benefits.

Prioritization Criteria	Evaluation Key
Is the process currently being supported by a legacy system that is likely to fail in the near future or no longer offers the desired functionality?	**Yes**, relying on a system that may fail at any time is considered a high risk for data loss and inability to run reports or issue payments to contractors. Demonstrating that a system failure may keep the agency from making commitments to their stakeholders provides a strong business case to fund implementation of a newer system. Additionally, a new system may offer better functionality not presently available in the legacy program to meet current business practices. **No**, the current system in use may not be outdated, or may be well-supported to add desired functionality.
Will this improvement support/realize an agency-wide initiative/directive (e.g., reducing overhead costs or reducing lost project documentation?)	**Yes**, supporting an agency-wide initiative/directive will enable the agency to gain momentum within the agency and buy-in from management and staff. **No**, the agency has not identified an agency-wide initiative/directive.

Table 21. Additional prioritization criteria to assess level of investment.

Prioritization Criteria	Evaluation Key
Implementation/integration, internal agency/staff time, software/licensing, software developing, on-going software maintenance and upgrades, and contractor compliance	Costs will vary—nevertheless, the cost of implementation is relative to the benefit that can be realized by the implementation of new technology. A thorough benefit-cost analysis should be conducted to determine the ROI for implementing the improvement opportunity. This financial investment analysis should be part of an overall business case for implementation of a new improvement opportunity. Additionally, the business case should incorporate investments that line up with the agency budget cycle.

Table 22. Additional prioritization criteria to assess how to leverage existing resources.

Prioritization Criteria	Evaluation Key
Does the agency have existing licenses/software that can be leveraged for e-Construction tools to minimize investment costs?	**Yes**, leveraging existing licenses will enable agencies to repurpose or expand upon existing software licensing agreements to optimize overall investments. In many cases, one functional area of the organization already owns an enterprise licensing agreement with a vendor, but the software platform may not be used across the enterprise. Additionally, vendors may offer a bulk discount for procuring additional software packages. While it is not necessary to purchase all e-Construction tools from one vendor, it is important to understand how each tool can integrate with existing systems and how the support team will be able to support the entire enterprise. For example, data entered in a construction daily diary electronic system can be extracted to another system to support mobility and accessibility (e.g., mobile mapping applications and cloud-based systems).) **No**, acquiring a new system will require a large initial investment.
Can the agency leverage existing resources (e.g., IT staff, system administrators) to facilitate process improvements?	**Yes**, since internal staff will ultimately become the end users, their involvement is critical to ensure successful implementation. Agencies can create a dedicated implementation team or have staff split their existing responsibilities with implementation responsibilities. Further, internal staff may be used to provide on-going technical support and training. **No**, hiring external resources can be costly, especially when internal involvement (and the institutional knowledge that comes with it) is critical to successful implementation.

Table 23. Additional prioritization criteria to assess likelihood of success.

Prioritization Criteria	Evaluation Key
Has the agency implemented systems/tools for related steps/activities that can support this process?	**Yes**, having systems/tools in places for related steps/activities gives the agency a stepping stone to build from (e.g., having a project collaboration tool and a project construction management system in place and then deciding to implement mobile devices). This will also allow the agency to increase the benefits it is yielding for the existing systems/tools. **No**, the agency does not have any systems/tools in place for related steps/activities.
Has this improvement opportunity been piloted at the agency to an extent?	**Yes**, piloting the initiative first before deciding to move forward with agency-wide implementation enables the agency to test staff receptiveness to adapting the technology and obtain an estimate of cost and benefits. A pilot project can also yield critical lessons learned to apply toward agency-wide implementation. **No**, if the agency has not piloted the initiative, it will not have any benchmarks for benefits and costs.
Number of parties involved in the current process (internal/owner, designers, contractors, others)	A **higher number** of parties involved translates into more users that will benefit from the improvement opportunity. A **lower number** of parties means that the improvement opportunity will have a smaller impact.
Are business processes clearly documented?	**Yes**, clearly documented business processes make it easier to transition paper processes into electronic processes. **No**, without clearly documented business processes (that reflect the agency's most current practices), it will be more challenging to convert a paper process into an electronic process.
Is there an identified funding source for implementation?	**Yes**, the agency is able to fund the improvement opportunity as part of a broader initiative or a previously identified need. **No**, without an identified funding source it may be harder to get the initiative off the ground.

Prioritization Criteria	Evaluation Key
Is staff committed and involved in supporting implementation (despite staff constraints that may exist)?	**Yes**, staff commitment and involvement are critical to developing a tool/system that meets all agency/user needs. **No**, lack of staff commitment and involvement will impact the likelihood of success. If staff are not committed to the initiative, it will be difficult to get the labor resources needed for implementation.
If there a champion and support/buy-in from executive management, internal staff, and the industry/local contractors' association?	**Yes**, support from internal agency staff and the industry/local contractors' association is critical to successful implementation. A champion can help educate staff on the benefits of the system. **No**, the absence of a champion and management/staff support will impact the likelihood of success of the initiative. The agency may face substantial resistance that could be a roadblock for implementation.
Does the agency have technical staff (e.g., an engineering automation group, engineering application services group, design technical services, etc.) that can provide support and expertise in technologies used for engineering processes?	**Yes**, having in-house expertise gives agencies an advantage in determining which solutions will best suit the agency's needs given existing resources. **No**, the agency does not have in-house technical staff to provide expertise. However, the agency can leverage some of this knowledge from peer agencies.

Seamless integration across all improvement opportunities

Although improving each area independently allows state transportation departments to identify significant benefits, integrating various areas would allow them to maximize the benefits of e-Construction by offering more benefits for their investments. Agencies that have transitioned multiple processes from paper to electronic should consider integrating those processes in order to help streamline the project delivery process and achieve additional efficiencies that will increase benefits significantly (more than the sum of the parts). The following is an example of a seamless integration scenario:

- Use of a common database for the complete project delivery process to reduce multiple data entry, ensure more complete and accurate project data, increase efficiency of information retrieval, and provide data for analysis, reporting, and management reporting.

- Use of a pre-construction management system to prepare bid materials. Contract language in bid materials would specify the requirements of geospatial data so that there is a common data environment for design, construction, and construction management.

- Integration of the pre-construction management system with the electronic bidding tool to seamlessly upload bid materials to the agency's electronic bidding tool.

- Use of electronic bidding and digital signatures by contractors to submit bids, and subsequently by the agency to review bid data (including verifying bid bonds) and conducting bid analysis.

- Integration of construction data into the agency project management system to allow for agency-wide views of all project information, including budgets, expenditures, commitments, status, schedule, and other key project metrics.

- Integration with federal systems for FHWA project authorizations and modifications.

- Linking of the bid submittal information (e.g., contract unit prices, pay items, etc.) with the construction management system for project initiation.

- Use of 3D modeling data for AMG for site preparation, asphalt and concrete paving, and other activities.

- Management of contract administration, contract records, daily work reports, contractor payments, materials management, and laboratory inventory management using the project construction management system, which should have workflows built in to ensure seamless document routing.

- Use of a project collaboration tool to effectively manage all contract documents, including the ones listed above in the construction management system.

- Integration of mobile devices with key agency systems, including the project collaboration tool and project construction management system to access, review, revise, and approve various documents in the field.

- Use of the construction management system to conduct the final close-out process, including final acceptance, confirm all approvals and signatures are in place, and send the project for final payment to financial and accounting systems.

- Transition of project documents from the project collaboration tool to the agency's enterprise document/content management system once the project is completed.

The feasibility of such an integration will vary by each agency and depend on the specific set of tools and systems in use.

Estimating Quantitative Benefits and Costs

In addition to the prioritization criteria, agencies should consider the quantitative benefits and costs of each improvement opportunity to help build the business case for improvements.

This section describes the BCA tool developed to help state transportation departments calculate ROI for the implementation of each improvement opportunity. The tool is an Excel-based template and was developed as a companion document to this report. The purpose of the ROI tool is to automate the BCA calculations using a user-friendly and flexible template that can be used by any agency.

Benefit Cost Analysis Template

The benefit cost analysis template is comprised of an input sheet to enter benefits and costs, as well as a calculation sheet that computes the total benefits and costs and the ROI. The template documents different cost and benefit categories and includes planning-level estimates based on certain benchmarks. The template is designed to be user-friendly and flexible so that agencies can change:

- Benefit/cost categories.
- Benefit/cost numbers.
- Implementation timeframe and benefits realization timeframe.

In addition, instructions on how to use the template and guidance on how agencies can estimate their own benefits/costs are incorporated throughout the template.

General Information

A number of standard terms are used in BCA and ROI calculations, which are defined in Table 24, and were taken into account when developing the template.

Table 24. Definitions of terms used in BCA and ROI calculations.

Term	Description
Total costs	Includes initial cost plus any reoccurring costs.
Total benefits	Includes total estimated benefits.
ROI	Return on investment for specific time period.
Break-even Year	The year in which the benefits first exceed the costs of implementation.

Template Organization

The template has a number of tabs that provide the framework for the BCA and ROI calculations and potential timeline for implementing each of the e-Construction improvement opportunities identified in this study. Each improvement opportunity has three tabs: Inputs, BCA, and Timeline. Table 25 describes each of the tabs used in the template.

Table 25. Description of worksheet tabs used in the ROI template.

Worksheet Tab	Description
Inputs	The input tab is where the user inputs benefits and cost information. This tab has two parts: Part A covers anticipated (quantitative) benefit streams and Part B covers costs. Cells highlighted in green are inputs (i.e., unlocked cell that can be edited), and cells highlighted in white are formulas calculated based on the inputs provided (i.e., locked cell that cannot be edited). This legend is illustrated in Figure 4.
BCA	The BCA tab is the reported calculations based on the information the user enters in the *Input tab*. The BCA tab has ONLY ONE user input field, which is the ROI timeframe. The template default is seven years, which is a typical timeframe used for implementation of information technology. A shorter timeframe may be selected based on software contract terms, depreciation of technology, and other factors.
Timeline	This tab provides a general timeline for deploying the specific e-Construction opportunity. There is no user input in this tab.

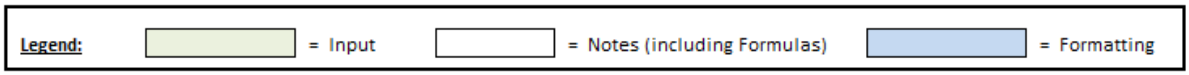

Figure 4. Screen capture. Legend for data cells in ROI spreadsheet template.

In addition, a worksheet at the end of the Excel file includes benefits that could be derived from integrating various improvement opportunities.

Benefit and Cost Inputs

The benefit and cost inputs are based on a hypothetical agency with an annual construction program of $800 million and assumes that the agency has no existing software licensing in place and is implementing a COTS system.

Benefit streams are calculated based on a set of input categories, which vary depending on the improvement opportunity. However, common input categories include the agency's annual construction program, personnel costs, materials costs, time savings, etc., as shown in Figure 5. The research team performed four case studies to collect project-level data from Iowa, Michigan, Missouri, and Utah. Additionally, a thorough ROI analysis prepared by the Pennsylvania DOT and prior studies were used along with the data from the four case studies to develop benchmarks. These benchmarks validate the planning and program level estimates that agencies can confidently use in their own estimate calculations. This exercise was intended to fill the benefits documentation gap that currently exists.

Table 1. Benefits Inputs

Input Category	Input	Notes/Assumptions	Benchmark Data
Annual construction program ($)	$ 800,000,000	Enter the annual construction program. This value can be obtained from the Construction Engineering Office.	
% of estimated annual savings from non-responsive low bids due to math or clerical errors	0.25%	Based on a percentage of contracts on which the the lowest bidder is deemed non-responsive due to math or clerical errors. This amount is estimated to be 0.25% of the construction program. Agencies can obtain an estimate of their non-responsive bids from the procurement department.	• Caltrans (estimated annual construction program size of $ 11.2 b) estimated that non-responsive bids due to clerical or math errors cost Caltrans over $12 million. • Indiana DOT conducted a cost benefit analysis in 2007 and found that irregular bids cost the agency $2.9 million in FY 2006.
# of hours saved by staff in bid data entry, evaluation, reporting and verification/validation	12	This value presents the number of hours that could be diverted to other work instead of evaluating bids (most of which would be done by automated systems).	• Iowa indicated that it reduces the processing time per bid letting by 1.5 days • Missouri DOT estimates a savings of 71 FTE-hours/bid letting to process, bid data entry, evaluate, create reports, check bid bonds, etc. • New Jersey, prior to electronic bidding, contracted a full time person to make paper copies of plan sets for contractors • Texas DOT has reduced the time it takes to process electronic bids and post results from approximately 4.5 to 1.5 hours (e-bidding is not mandatory, only 50 to 70 contracts were submitted electronically) • Wisconsin DOT estimated that it saves 48 FTE-hours each bid letting through streamlined Internet bidding processes
Hourly rate for staff (fully loaded)	$ 65	This presents the hourly salary for staff evaluating bids. This number includes overhead costs (fringe benefits).	
# of projects bid per year	300	This value is the annual average number of contracts advertised in the last 12 months. This number can be requested from the Contracts Group	

Figure 5. Screen capture. Input field to calculate benefits for implementation of electronic bidding and contractor selection.

In addition to the benefits streams, another input included in the template is the phasing of benefits—that is, the percent of benefits realized each year since there may be a gradual ramp up

of benefits immediately after implementation before an agency realizes 100 percent of benefits, as shown in Figure 6.

Table 2. Anticipated Benefit Streams and Percentage Realized by Year									
Anticipated Benefit Stream	Calculation/Assumptions	Anticipated Benefits (in $)	Percentage of Anticipated Benefits Realized on Annual Basis. *(Phasing of benefits reflects the gradual progression to making electronic bids mandatory)*						
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Estimated savings resulting from non-responsive low bids due to math or clerical errors.	Annual construction program * % of estimated annual savings from non-responsive low bids. Assumption is that agency receives no benefits in the year of implementation (year 1), 25% in year 2 (when electronic bidding could be optional), 75% in year 3 and 100% thereafter.	$ 2,000,000	0%	25%	75%	100%	100%	100%	100%
Estimated savings resulting from improved workforce utilization	Number of bid lettings * Number of hours saved per bid* fully loaded hourly rate.	$ 234,000	0%	25%	75%	100%	100%	100%	100%

Figure 6. Screen capture. Anticipated benefit streams and phasing of benefits for electronic bidding and contractor selection.

Cost categories, as shown in Figure 7 and Figure 8, were based on commonly used tools by state transportation departments for the following components:

- Pre-implementation planning consultant.
- COTS software licenses.
- COTS software maintenance.
- Systems integration services.
- Managed services support.
- Hardware and other technical infrastructure.
- Hardware and infrastructure maintenance.
- On-site training/web-based training.
- Hardware refresh.
- Agency staff cost during project.
- Agency staff cost to support system ongoing.
- Systems integration services for upgrade.

All the costs and benefits are presented in real dollars (today's dollars), which eliminates the need to use an inflation factor for costs and a discount factor for benefits.

Table 3. Staff Costs for Implementation and Ongoing Support						
Staff	Time (# of Years)	FTE	Base Salary	Overhead Rate	(Salary + Overhead) * FTE* # of Years	Notes
Contracts and Specifications Engineer (Implementation)	0.75	0.50	$ 75,000	80%	$ 50,625	
Preconstruction Staff (Implementation)	0.75	0.50	$ 75,000	80%	$ 50,625	
Information Technology Staff (Implementation)	0.75	2.00	$ 75,000	80%	$ 202,500	
Preconstruction Staff (Training)	0.08	1.00	$ 75,000	80%	$ 11,250	Time (# of Years): This value is for the number of years the staff members will be required, and is based on the implementation timeline.
Information Technology Staff (Ongoing Support)	1.00	0.25	$ 60,000	80%	$ 27,000	FTE: This is the expected Full Time Employee (FTE) equivalent dedicated to the implementation
Total (Implementation)					**$ 315,000**	Base Salary: This is the estimated base salary for the employee. This value may be obtained from HR and an average salary may be used.
Annual Ongoing Support					**$ 27,000**	Overhead Rate: This is the overhead rate used to account for fringe benefits, and can be obtained from HR

Figure 7. Screen capture. Staff costs for implementation of electronic bidding and contractor selection.

Table 4. Costs and Percentage Incurred by Year									
Costs	Notes/Assumptions	Total Costs	Costs Incurred on Annual Basis						
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Pre-implementation planning consultant	Enter the cost for consultant support to help with the pre-implementation planning.	$ 135,000	$ 135,000	$ -	$ -	$ -	$ -	$ -	$ -
COTS software licenses	The pre-populated values assume that the software is acquired through the Software as a Service (SaaS) model, and all payments are in real dollars (escalation in cost will be consistent with the inflation rate).	$ 140,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000
COTS software maintenance	Enter any software maintenance cost that is **NOT included** in the annual software licensing/subscription. Generally, software maintenance is a percentage of the software license cost in a traditional on-premise installation model (software installed on DOT servers). SaaS generally does not require an additional maintenance fee.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Systems integration services	Systems integration services includes installing and configuring the software for the agency and integration with existing DOT systems (e.g. cost estimation, project mgmt., & financial). This is typically a line item in the e-bidding solution contract. We have assumed that 80% of the cost will be in year 1 and 20% of the cost will be in year 2 based on the general implementation timeline.	$ 500,000	$400,000	$ 100,000					
Managed services support	This is the cost to manage the services. This is assumed to be included in the software licensing cost.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Hardware and other technical infrastructure	It is assumed here that no additional hardware or updates are required to the technical infrastructure since the software is provided as a service and not hosted on premise (on DOT servers).	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Hardware and infrastructure maintenance	Enter the cost for hardware and necessary software maintenance (applicable in an on-premise installation).	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Hardware replacement/updates	Enter the cost for hardware replacement/updates. Hardware is generally upgraded every 3-5 years. You may assume a cost equal to the original hardware and technical infrastructure since the costs are presented in real dollars (today's dollars).	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Agency staff cost during implementation	The staff costs here are based on inputs in Table 3. Based on the general implementation timeline, we have assumed that 90% of the cost will be in year 1 and 10% in year 2. This includes time spent by staff to be trained on the new system(s).	$ 315,000	$283,500	$ 31,500	$ -	$ -	$ -	$ -	$ -
Agency staff cost to support system ongoing	The staff costs are based on inputs in Table 3. Ongoing support begins in the year that implementation is complete (Year 2 in this case).	$ 162,000	$ -	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000
Systems integration services for upgrade	Enter the estimate to upgrade the software. Upgrades are assumed to take place every 3 years after original implementation is complete, and cost 15% of the original implementation. This cost accounts for any interface and other changes required in the SaaS model.	$ 150,000	$ -	$ -	$ -	$ 75,000	$ -	$ -	$ 75,000

Figure 8. Screen capture. Costs and percentages incurred by year for implementation of electronic bidding and contractor selection.

Benefits Cost Analysis Calculation

Based on the inputs provided in the inputs sheet, the template will calculate the following values, which are shown in Figure 9:

- Total benefits.
- Total costs.
- Net benefits.
- Cumulative net benefits.
- Break-even year.
- ROI based on the selected timeframe (default is seven years).
- Average annual cost.
- Average annual net benefits.

In addition, the sheet allows for entry of qualitative benefits (ones that cannot be assigned a dollar value) and includes a set of qualitative benefits gathered/developed by the project team.

Benefit Cost Analysis Calculations

Improvement Opportunity Area: Electronic Bidding and Contract Award

Includes bid preparation, submittal, acceptance, evaluation, and contract award through an electronic system. Electronic bidding and contract award is among the most mature of e-Construction practices; nevertheless, many state transportation departments are not maximizing the full benefits of this digital process. In many cases, the processes for preparing and evaluating bids are still manual. The primary benefits are quicker and more accurate bids due to electronic/automated checking of formulas and real-time submittal, and the reduction of carbon footprint.

Legend: = Input = Notes (including Formulas) = Formatting

Benefits (Qualitative)

Reduced or eliminated incomplete or irregular bids due to electronic bidding validation as responses are prepared

Electronic bids can be submitted up to the last minute before bid opening, allowing contractors to spend more time on developing the most competitive responses to bids, which can lead to savings on project costs for the DOT.

Reduced risk for error (including data entry errors, lost documentation, and reduced errors in bid submittals, etc.) allowing DOTs to award more bids to the lowest bidder

Prospective bidders no longer have to carry around bid documents since the information is now available online

Benefits (Quantifiable)	Total	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Estimated savings resulting from non-responsive low bids due to math or clerical errors.	$ 10,000,000	$ -	$ 500,000	$ 1,500,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000
Estimated savings resulting from improved workforce utilization	$ 1,170,000	$ -	$ 58,500	$ 175,500	$ 234,000	$ 234,000	$ 234,000	$ 234,000
Total Benefits	***$ 11,170,000***	*$ -*	*$ 558,500*	*$ 1,675,500*	*$ 2,234,000*	*$ 2,234,000*	*$ 2,234,000*	*$ 2,234,000*

Costs	Total	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Pre-implementation planning consultant	$ 135,000	$ 135,000	$ -	$ -	$ -	$ -	$ -	$ -
COTS software licenses	$ 140,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000
COTS software maintenance	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Systems integration services	$ 500,000	$ 400,000	$ 100,000	$ -	$ -	$ -	$ -	$ -
Managed services support	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Hardware and other technical infrastructure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Hardware and infrastructure maintenance	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Hardware replacement/updates	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Agency staff cost during implementation	$ 315,000	$ 283,500	$ 31,500	$ -	$ -	$ -	$ -	$ -
Agency staff cost to support system ongoing	$ 162,000	$ -	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000
Systems integration services for upgrade	$ 150,000	$ -	$ -	$ -	$ 75,000	$ -	$ -	$ 75,000
Total Costs	***$ 1,402,000***	*$ 838,500*	*$ 178,500*	*$ 47,000*	*$ 122,000*	*$ 47,000*	*$ 47,000*	*$ 122,000*
Net Benefit (positive indicates benefit)	***$ 9,768,000***	***$ (838,500)***	***$ 380,000***	***$ 1,628,500***	***$ 2,112,000***	***$ 2,187,000***	***$ 2,187,000***	***$ 2,112,000***
Cumulative Benefit		***$ (838,500)***	***$ (458,500)***	***$ 1,170,000***	***$ 3,282,000***	***$ 5,469,000***	***$ 7,656,000***	***$ 9,768,000***

Breakeven Year, not accounting for qualitative benefits	Year 3
Return on Investment (please select timeframe) === 7 Years	697%
Average Annual Cost	$ 200,286
Average Annual Net Benefit	$ 1,395,429

Figure 9. Screens capture. Benefit cost analysis for bidding and contractor selection.

The calculations use a seven-year time frame since this covers a longer time frame than implementation and captures the full benefits realization for at least a couple of years. In addition, it was assumed that hardware/software upgrade cycles occur every three to five years, which falls within this seven-year timeframe. The template has a built-in formula that enables agencies to calculate the ROI for any time frame (seven years or less), as shown in Figure 10. This field illustrates the flexibility in the template to select the desired time frame. The ROI will automatically update based on the number of years that is selected.

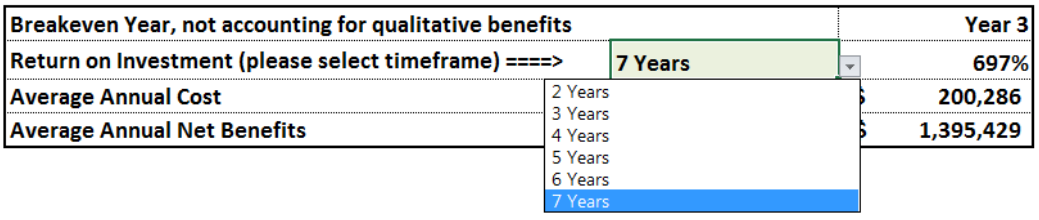

Figure 10. Screen capture. Return on investment timeframe selection.

Dashboard

Table 26 presents the ROI calculated for each improvement opportunity using benchmarks and planning-level estimates. Digital review and mobile devices have the quickest break-even year, while digital review of project documents yields the highest seven-year ROI.

Table 26. Summary of planning level estimates.

Improvement Opportunity	Break-even Year (from start of project planning)	7-Year ROI (rounded to nearest quarter) [4]
Electronic bidding and contract award	Year 3	700%
Digital PS&E	Year 3	325%
Digital review of project documents	Year 2	775%
Project construction management	Year 4	250%
Digital management of construction documentation using a project collaboration tool	Year 5	250%
Requirement of digital as-built records	Year 3	125%
Mobile devices	Year 3	200%

As seen from Table 26, moving to a digital review of project documents is expected to yield the most benefits in the shortest time frame. This is primarily due to a prevalence of cloud-based tools available for a reasonable price that can be implemented easily to meet this goal, and a high amount of savings derived from reduced printing needs. Project construction management and project collaboration tools would take the longest to implement and institutionalize, resulting in a longer time to break even and a lower ROI over a seven-year timeframe. That said, all the opportunities identified are expected to yield a robust ROI and yield benefits quickly to the agency after implementation is completed.

These benefits and break-even years will vary per agency based on various factors such as the following:

4 The return on investment percentages have been rounded to the nearest 25th, 50th, 75th, and 100th percentage.

- Agency (size, current practices, urban/rural setting).
- Existing maturity in e-Construction.
- Project scope (new construction, major rehabilitation, minor rehabilitation).
- Project location (close to a central/urban location, remote).
- Tool used (enterprise tools where costs are divided among projects or a software purchased as a service for the project).

A more detailed benefit cost analysis can be found in the BCA template.

Benefits Realization

When estimating benefits realization, agencies should be prepared for temporary losses in productivity as staff become acclimated with the new systems/tools before productivity increases and there is a positive net benefit. Figure 11 depicts an illustration of a learning curve, which shows how staff productivity is affected over the period that a technology is being deployed. This concept shows that productivity hits the lowest level during the beginning of a technology being deployed before increasing to its full potential when staff have become familiar with the new tools.

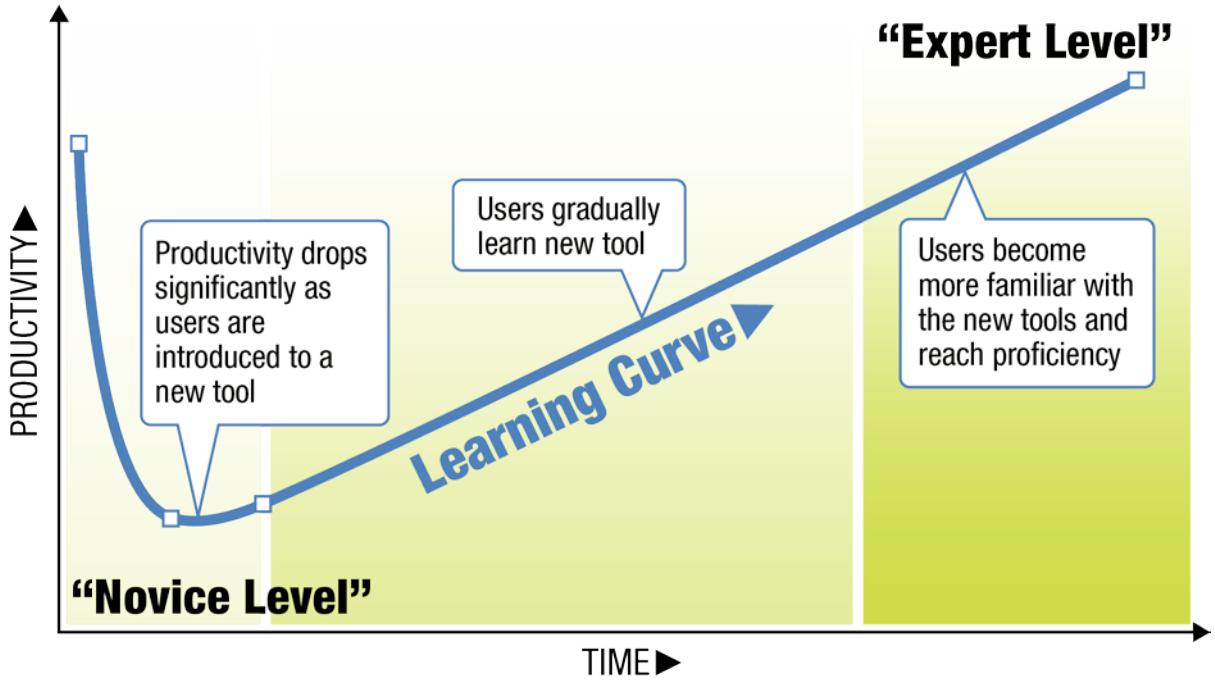

Figure 11. Graph. Traditional learning curve observed when adopting new technology or methods.

Factors Affecting Benefits Realization

The benefits yield varies across agencies and projects. Some factors that can affect the amount of benefits an agency will yield include the following:

- Agency (size, current practices, urban/rural setting).
- Existing maturity in e-Construction.
- Project scope (new construction, major rehabilitation, minor rehabilitation).
- Project location (close to a central/urban location, remote).
- Tool used (enterprise tools where costs are divided among projects or a software purchased as a service for the project).

Every project yields savings, but projects that require more documents result in more savings (through elimination of mailing, paper, scanning, etc.). Typically, new construction, major rehabilitation, and complex urban projects result in more benefits. Although minor rehabilitation projects also yield benefits, those benefits are not as apparent. A larger, more complex project tends to have larger plan sets and a longer timeframe, therefore saving more money than a project with fewer documents and a shorter time frame. Another factor that has a significant impact on benefits realization is which e-Construction solution is selected and how the new processes and technology are deployed. A solution that is user-friendly and can streamline processes will be more likely to have a quicker rate of adoption. In addition, integrating a single statewide e-Construction solution that aligns with standardized workflows can help train staff more effectively and efficiently because everyone follows the same process for every project. One benefit that is difficult to quantify, but is significant, is having a single source of truth for project data. As the agency captures accurate data at the source and manages it in an enterprise solution, this information can be propagated to other systems and used multiple times realizing even more benefits than the elimination of paper.

Implementation Activities and Timelines

The project activities are divided into four key categories:

- Pre-implementation planning phase.
- System implementation phase.
- Project management.
- Organizational change management.

The primary tasks/activities for each category are described in more detail below. Not all tasks will be applicable to all improvement opportunities.

Implementation Activities

Pre-Implementation Planning Phase

The suggested task/activities in the Pre-implementation Planning phase are illustrated in Figure 12.

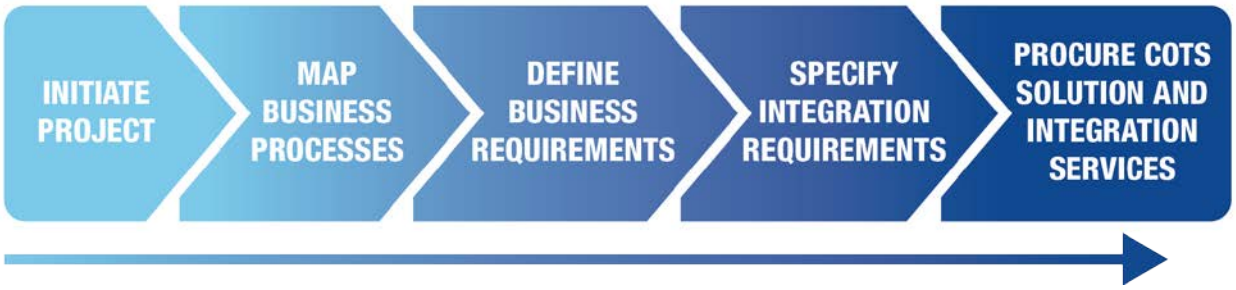

Figure 12. Flowchart. Sequence of pre-implementation planning activities.

1. **Initiate project.** This task involves the development of a project charter, a project management plan to outline management processes to be followed during the project, and the initial project work plan. A project kick-off meeting with all key stakeholders should also be conducted.

2. **Map project delivery business processes.** Understanding current business processes is critical because the technical requirements for any new system will need to support the agency processes. Furthermore, it is important to identify whether the current processes are based on preference, policy, or by law. Typically, mapping business processes is a documentation of workflows that includes brief narratives and identifies issues or bottlenecks with each of the tasks performed. Additionally, part of this process should include identifying unnecessary steps previously tied to paper-based methods that can be eliminated upon deployment of a new system.

3. **Define system requirements to meet the business needs**. The system requirements define the functional capabilities needed in an e-Construction solution to meet the organization business needs and should be organized logically by major process and sub-processes. Furthermore, the requirements should define the type of data that will be used by the system and its sources, formats, and any special characteristics. Other general requirements include ease of use, common look and feel, analysis and reporting tools, any desired customization, automated workflows, security, audit trails, archiving, online help, user documentation, training, technical support, and warranty.

4. **Specify integration requirements.** These types of requirements typically involve interface requirements to integrate with existing or planned agency systems and conversion of any legacy data into the proposed system (e.g., integrating mobile devices with the agency's construction management system and project collaboration tool).

5. **Procure a COTS solution and professional services for implementation.** The request for proposal (RFP) for e-Construction applications should include the functional and integration

requirements of the proposed COTS solution and professional services to provide a system integrator. Most software vendors in the construction industry do their own product implementations versus some other types of application systems where multiple systems integrators may implement a COTS product and the agency may obtain a better price by first selecting the COTS software solution and then bidding out the implementation services separately. It is highly recommended to include a technical demonstration as part of the review and selection process scored on a combination of meeting the functional requirements and cost of the solution. There is always an option to issue a request for information to gain a better understanding of the available options to properly define language and requirements in the RFP.

System Implementation Phase

The suggested task/activities in the System Implementation phase are illustrated in Figure 13.

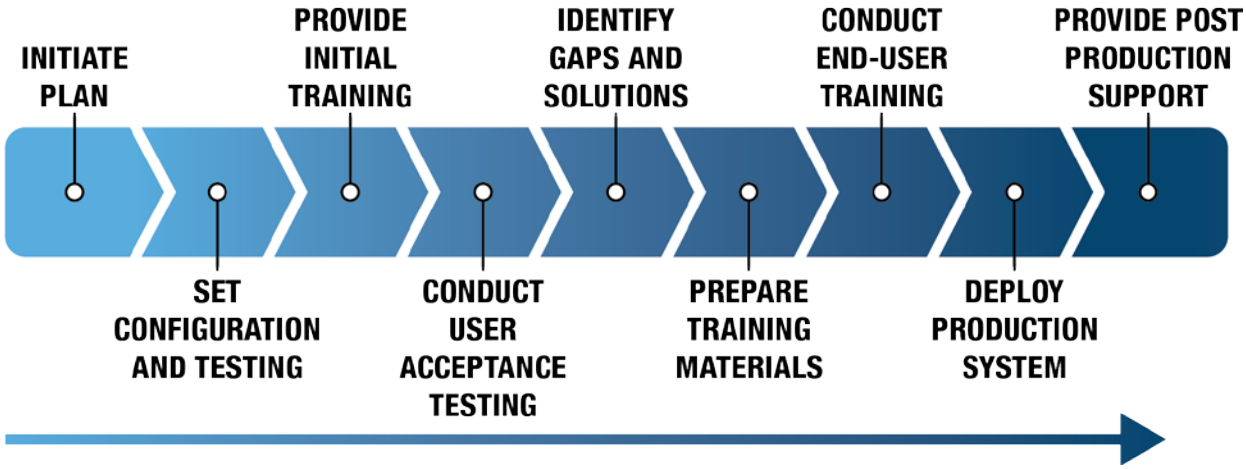

Figure 13. Flowchart. Sequence of system implementation activities.

1. **Initiate implementation plan.** Once a solution has been selected, an implementation kick-off meeting should be held between the project team and the system integrator to review and confirm functional requirements, define roles and responsibilities, set clear expectations, and finalize the details of the implementation approach, progress updates, and timeline.

2. **Set system configuration and perform testing.** The system integrator performs necessary configuration and customization of the system, as well as initial testing to verify system requirements and identify any issues to be resolved before pilot testing. It is highly recommended to import a small sample of legacy information (whether it is previously scanned documents or data from an older electronic system) to test the conversation process prior to full deployment. During this stage, the system should be set up in a testing environment that could be later used for initial user acceptance and pilot testing. Depending on the e-Construction area of improvement, the timeline for conducting a pilot may be a few weeks or a few months.

3. **Provide initial training.** The system integrator provides initial training to the implementation team and any other agency staff who will perform the user acceptance testing and support the system after implementation.

4. **Prepare for and conduct user acceptance test.** It is recommended that this be an agency-led activity and that the testing involves additional staff who have not been involved in the day-to-day project development activities.

5. **Identify gaps and create plan to provide solutions.** The system integrator should develop a plan to solve any technical issues identified during the user acceptance testing. The schedule may have to be adjusted depending on the severity of the issues encountered during testing.

6. **Prepare training materials and user procedures.** Typically, this material will be developed by customizing and enhancing the software vendor's base materials to meet the needs of the specific agency. The responsibility of this task should be clearly defined in the RFP.

7. **Conduct end-user training.** It is recommended to have the system integrator conduct a train-the-trainer training program and provide additional online training resources to keep the cost low. In addition, providing just-in-time training should be considered because it is common for staff to forget the material if the course was presented too far in advance of the application deployment.

8. **Execute the final data conversion and deploy production system.** This is the last step before moving into post-production support—the deployment of the production system based on the proposed plan. It is recommended to convert one region at a time if possible.

9. **Provide post-production support.** Typically, post-production support is 60 days. The system integrator provides technical support before turning the system over to the ongoing post-production support team during this 60-day time frame. This period typically constitutes the system acceptance, and final payment for the implementation services to the system integrator can then be issued.

Project Management Phase

Project Management tasks are performed throughout the project and include:

- Manage performance of all project activities.
- Maintain the project work plan.
- Prepare project status reports.
- Manage potential project scope changes that may arise.
- Conduct Project Steering Committee meetings.
- Manage project budget and financial plan.

Organizational Change Management Phase

Organizational Change Management occurs throughout the project and the tasks include:

- Identify impacts of the new system on the organization.
- Plan for and proactively manage the implementation of these changes throughout the project life cycle, including a structured stakeholder engagement and communications plan for central office and field staff.
- Manage and implement user training program on both the new system and new business procedures.

Potential Timelines for Improvement Opportunities

The potential timelines for implementation for each improvement opportunity are illustrated in Figure 14 through Figure 20.

Electronic Bidding and Contractor Selection

Figure 14 illustrates the timeline for electronic bidding and contractor selection. Our general time estimate is that the pre-implementation planning (which includes documenting the current process, identifying and defining improvement opportunities, defining system requirements, and selecting a system based on system requirements) would require about four months. This assumes that the agency can negotiate the purchase through a state contract instead of an open market bidding, which would require longer. The system implementation is estimated to take about five months, followed by one month of user training and three months of production support during which the implementation team addresses any issues that are identified during the first few months of system use.

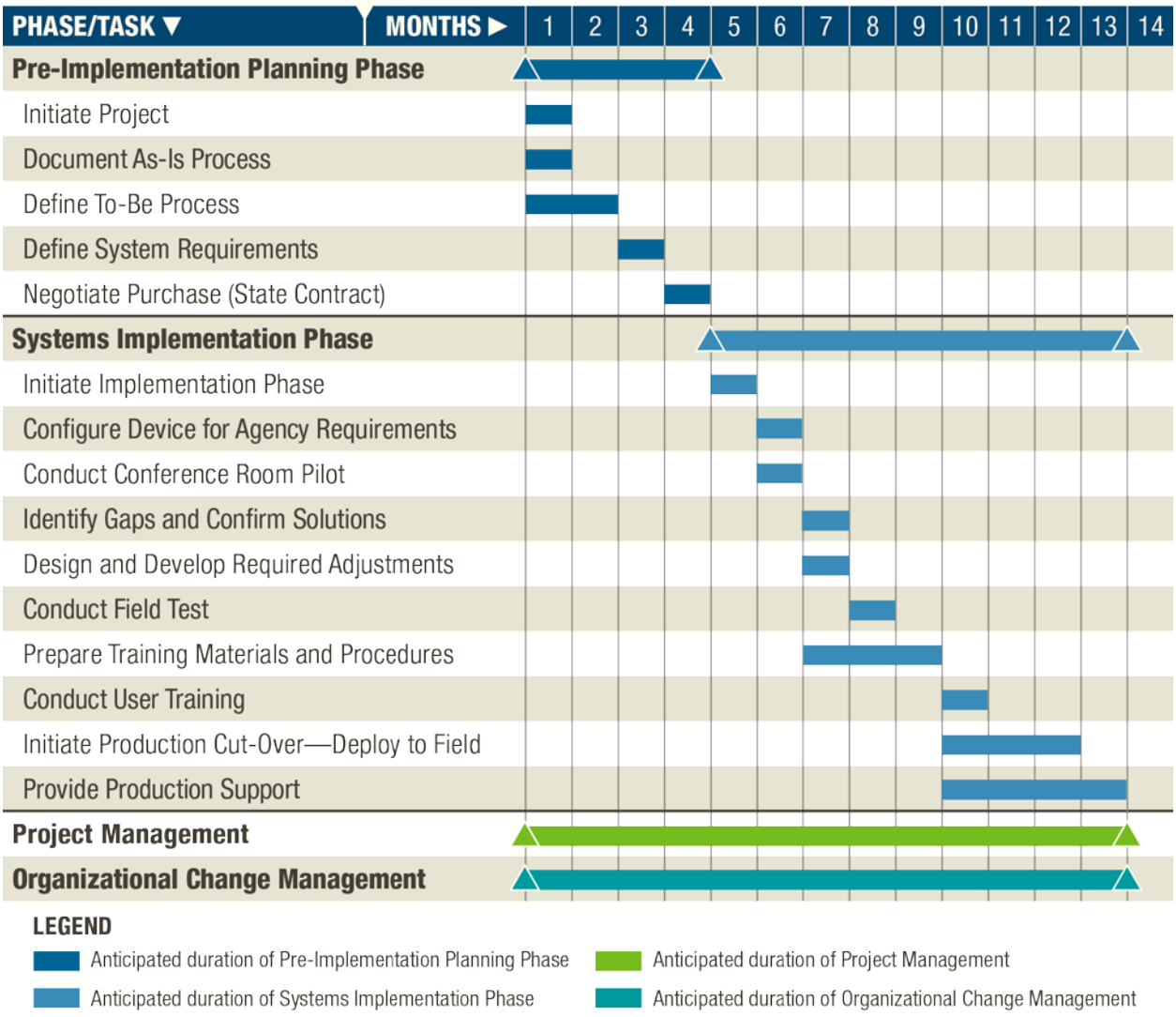

Figure 14. Timeline. Potential schedule for implementation of electronic bidding and contractor selection.

Digital Plans, Specifications, and Estimates

Figure 15 illustrates the timeline for digital plans, specifications, and estimates. Our general timeline estimate is that the pre-implementation planning (which includes documenting the current process, identifying and defining improvement opportunities, defining system requirements, and selecting a system based on system requirements) would require about five months. This assumes that the agency can negotiate the purchase through a state contract instead of an open market bidding, which would require longer. The system implementation is estimated to take about five months, followed by one month of user training and four months of production support during which the implementation team addresses any issues that are identified during the first few months of system use.

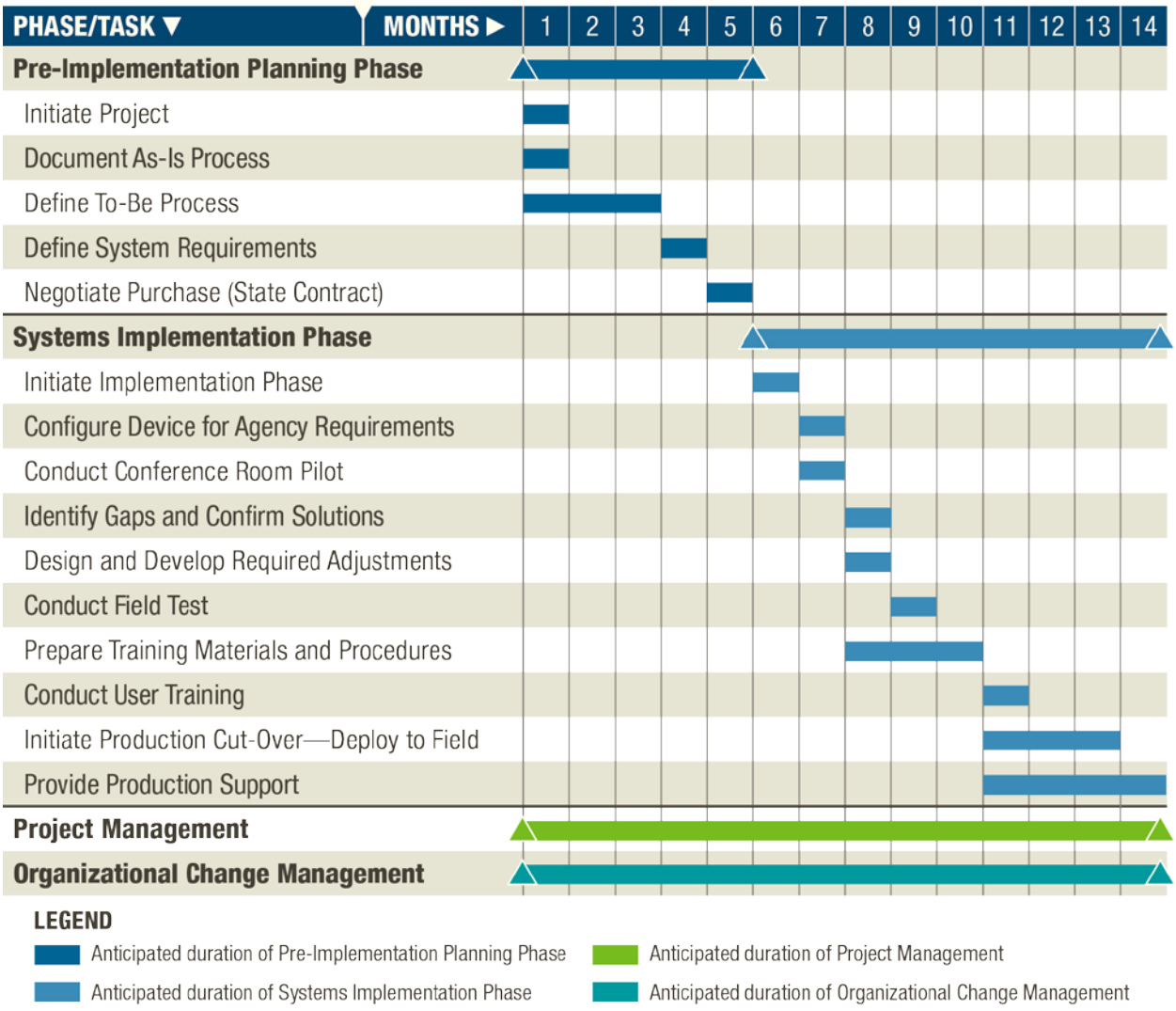

Figure 15. Timeline. Potential schedule for implementation of electronic PS&E.

Digital Review

Figure 16 illustrates the timeline for digital review. Our general timeline estimate is that the pre-implementation planning (which includes defining system requirements, preparing an RFP, selecting a system based on system requirements, and negotiating the contract) would require about three months since the process is generally simple. The system implementation is estimated to take about one month (purchasing software license and initiating its use), followed by one month of user training and two months of production support during which the implementation team addresses any issues that are identified during the first few months of system use. It is assumed that all documents to be reviewed electronically originated in electronic format (e.g., Microsoft Word files), making implementation easy.

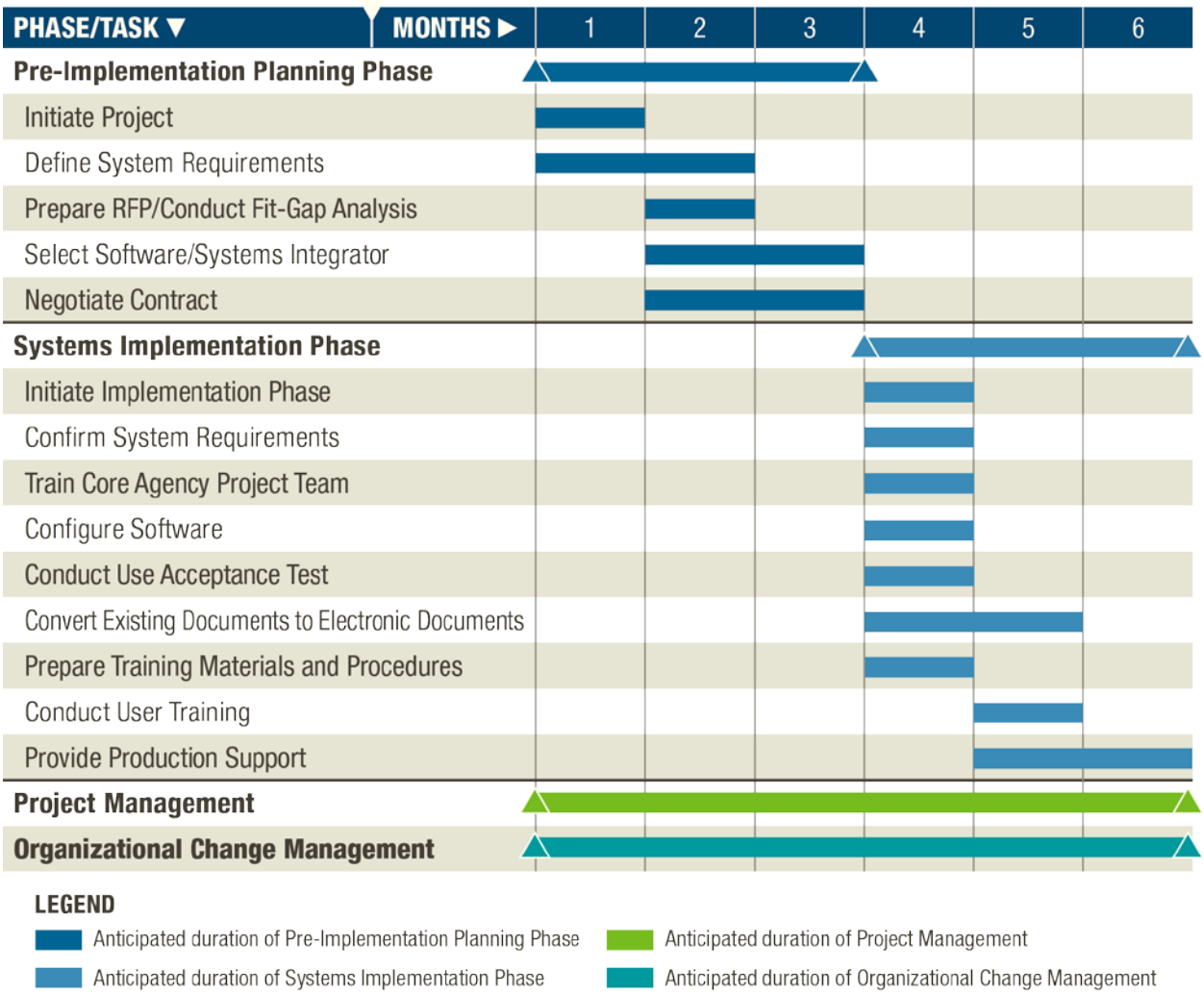

Figure 16. Timeline. Potential schedule for implementation of digital review.

Project Construction Management

Figure 17 illustrates the timeline for project construction management. A construction management system takes longer to implement than some of the other improvement opportunity areas identified since it is more complex and requires integration with various complex agency systems, such as financial and human resources management systems. This complexity also requires more testing activities, as reflected in the timeline below.

The general timeline estimate is that the pre-implementation planning would require about seven months. The system implementation is estimated to take about twelve months, including two months of user training followed by three months of production support.

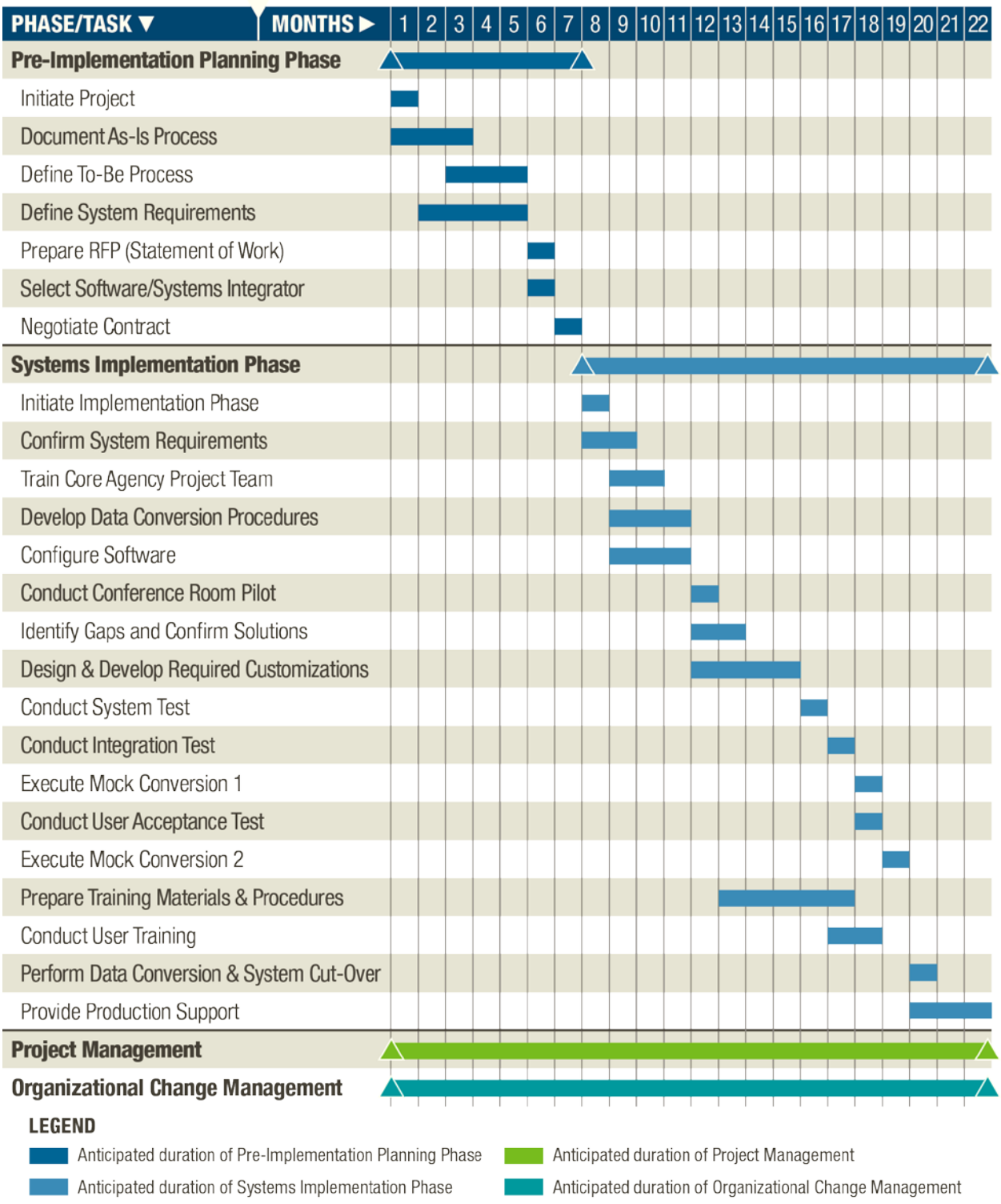

Figure 17. Timeline. Potential schedule for implementation of a project construction management system.

Project Collaboration

Figure 18 illustrates the timeline for project collaboration. Similar to implementing a construction management system, a project collaboration tool also takes longer to implement than some of the other improvement opportunity areas identified since it is more complex and requires more integration and testing activities.

The general timeline estimate is that the pre-implementation planning would require about eight months. The system implementation is estimated to take about twelve months, including four months of user training followed by one month of production support during which the implementation team addresses any issues that are identified during the first few months of system use.

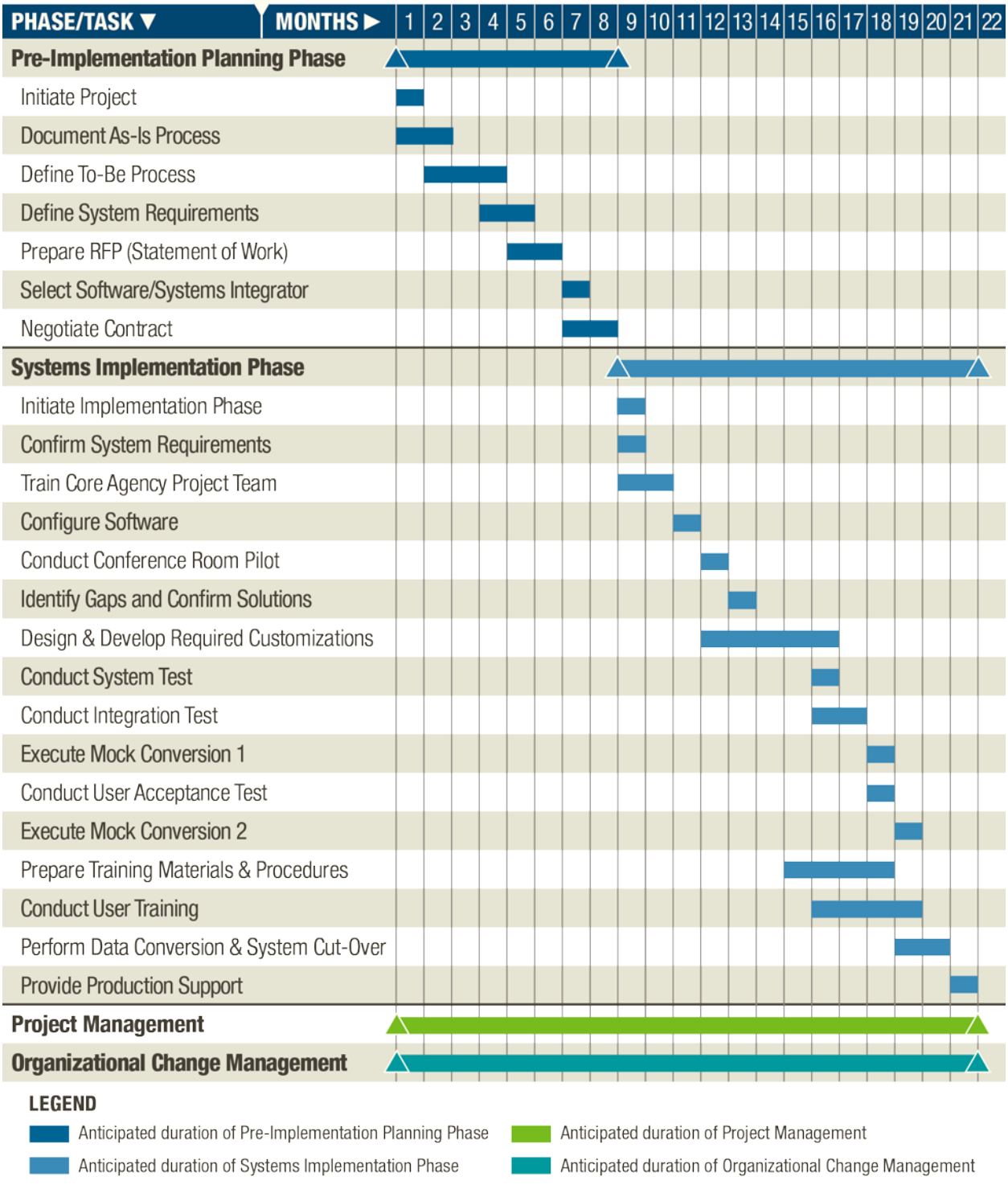

Figure 18. Timeline. Potential schedule for implementation of a project collaboration tool.

Digital As-builts

Figure 19 illustrates the timeline for digital as-builts. Assuming that the agency already implemented electronic PS&E, the step to implement digital as-builts may not be as daunting. However, it does require that the agency to work with stakeholders (e.g., contractors, construction, and maintenance staff). Implementation of digital as-builts requires defining what data will be collected, the format it will be delivered, and a process that will be used for review and acceptance of the final products. For agencies that produce their as-built records internally, there may be cost associated with data collection tools and software applications (e.g., mobile devices and mapping platforms). However, for agencies that require the contractor to deliver the as-built records, there may be no specific costs involved, although contractors may charge a little more for digital as-builts to compensate for the overhead of hardware and software tools they may need to complete that task. The agency will need to conduct some configuration to ensure that the correct symbols and terminology are used and that they are standardized and also conduct training to ensure staff is successful when migrating to the new electronic review process.

The general timeline estimate is that the pre-implementation planning would require about three months. The system implementation is estimated to take about one month, followed by one month of user training and two months of production support during which the implementation team addresses any issues that are identified during the first few months of system use. This timeline assumes that 3D engineered models have already been implemented for PS&E.

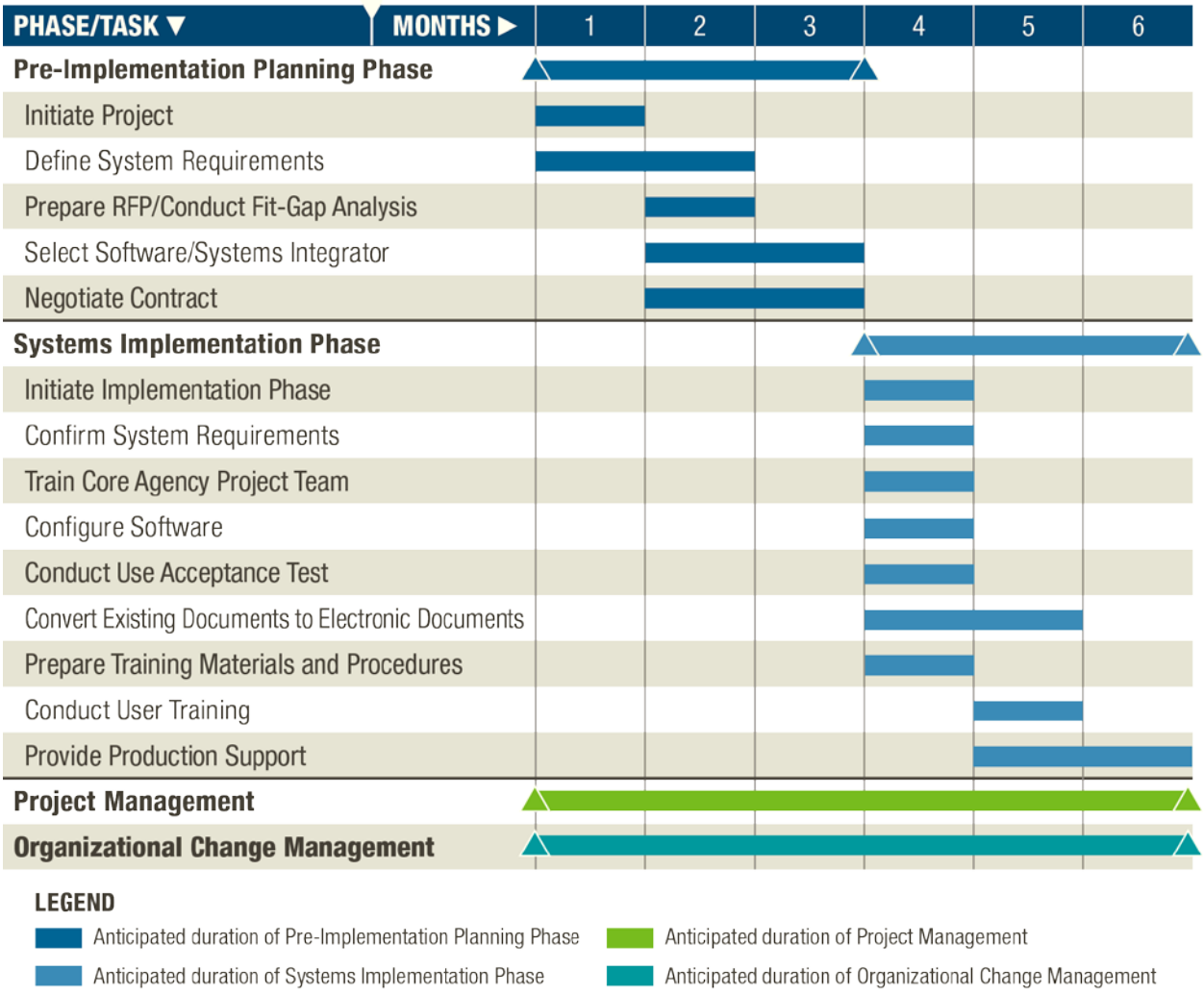

Figure 19. Timeline. Potential schedule for the implementation of requirements for digital as-built records.

Mobile Devices

Figure 20 illustrates the timeline for mobile devices. Our general time estimate is that the pre-implementation would require about four months. This assumes that the agency can negotiate the purchase through a state contract instead of open market bidding, which would require longer. The system implementation is estimated to take about six months, followed by one month of user training and four months of production support during which the implementation team addresses any issues that are identified during the first few months of system use. Use of mobile devices for activities other than construction inspection would require additional time for both pre-implementation planning and implementation.

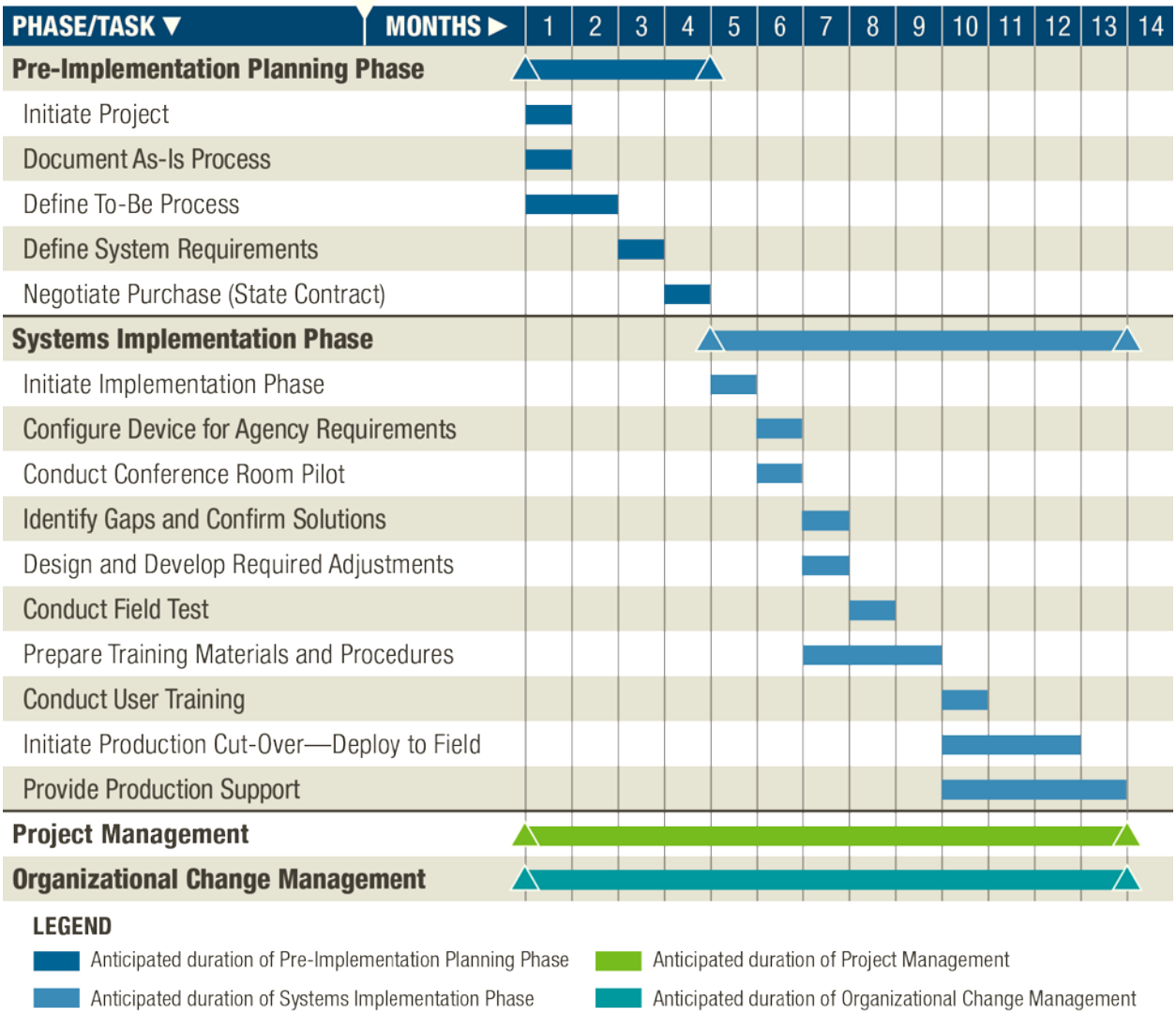

Figure 20. Timeline. Potential schedule for the implementation of mobile devices.

PROJECT SUCCESS FACTORS

Risk Management

Risk is defined as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives," which is consistent with the Project Management Institute's PMBOK® Guide definition of risk. (Project Management Institute 2013) Risk management aims to increase the probability and impact of positive events and decrease the probability and impact of events that could negatively impact system implementation. The risk management process begins during project planning and continues during project initiation through system design and implementation.

The output of the risk management process is the risk management plan (RMP), which is a standard project management tool that is used to document potential risks, assess the impacts of each risk, and identify strategies for responding to each risk. Risks are systematically scored to

determine whether they are high, medium, or low so that opportunities can be enhanced and threats can be reduced. The RMP is considered a living document, and it should be maintained throughout the life of the project by team members, with the project manager as the RMP owner.

The key components of a RMP are illustrated in Figure 21.

Figure 21. Illustration. Risk management process.

- **Risk Identification**. This is the process of identifying risks that could affect the project and their characteristics. Agencies can use the list of initial risks identified in Table 27, which appears later in this section, as a starting point and then conduct risk planning workshops with key stakeholder groups as part of project planning activities to identify additional risks. Each risk should be documented in the risk log.

- **Risk Analysis and Prioritization**. For each risk that is identified, agencies should assess the probability of occurrence using the standard probability scale and the level of impact using a standard impact assessment matrix in the event that the risk does occur. The product of probability and the impact will yield the Risk Score that will help determine Risk Planning.

- **Risk Planning**. This step involves developing a risk response plan for handling each of the high-priority risks identified in Risk Analysis and Prioritization. Typically, this activity is the result of iterative discussions between the project manager and a range of project stakeholders.

- **Risk Control and Monitoring**. This step includes executing the appropriate risk response plan to reduce the probability of a risk occurring or to mitigate its impact should it occur. This includes monitoring the progress in handling all risks that have occurred and continuing to identify and assess new risks that may emerge. This step should be carried out continuously during an implementation project.

Table 27. Initial inventory of potential risks and barriers.

Risk ID	Critical Success Factor	Risk Description	Risk Class	Probability 0.1 – 0.99	Impact 1 – 10	Risk Score (PxI)	Identified By	Risk Owner	Response	Risk Strategy and Notes
EC01	Executive Support	Executive sponsor is not identified	Internal	0.3	9	2.7	Implementation Team	e-Construction Business Champion	Avoid	Prepare and present business case to executive management Proactively seek executive sponsorship
EC02	Executive Support	Lack of staff resources to support implementation	Internal	0.5	9	4.5	Implementation Team	Project Sponsor	Mitigate	Identify resources and obtain IT and stakeholder collaboration early in the pre-planning phase
EC03	Executive Support	Lack of buy-in for implementation	Internal	0.7	10	7.0	Implementation Team	Project Sponsor	Mitigate	Communicate need and urgency of system/tool Share business case and benefits of system/tool
EC04	Funding	Funding constraints prevent implementation	External	0.6	9	5.4	Implementation Team	Project Sponsor	Mitigate	Develop a business case that clearly

Risk ID	Critical Success Factor	Risk Description	Risk Class	Probability 0.1 – 0.99	Impact 1 – 10	Risk Score (PxI)	Identified By	Risk Owner	Response	Risk Strategy and Notes
		from moving forward								justifies the investment Implement system/tool in phases and identify "quick-wins" that allow early successes to be shown and shared with decision makers
EC05	Action Plan	Digital signatures are not currently supported by policy or law	Internal/ External	0.5	7	3.5	Implementation Team	Project Sponsor	Mitigate	Identify requirements for implementing digital signatures Work with stakeholders to change policy or statutes to enable digital signatures
EC06	Action Plan	Timeline is unrealistic	Internal	0.3	5	1.5	Implementation Team	Project Sponsor and Project Manager	Mitigate	Develop detailed multi-phase

Risk ID	Critical Success Factor	Risk Description	Risk Class	Probability 0.1 – 0.99	Impact 1 – 10	Risk Score (PxI)	Identified By	Risk Owner	Response	Risk Strategy and Notes
										implementation plan Establish priorities for implementation Verify implementation timeline with other states and available benchmarks
EC07	User Involvement	Business processes are not clearly documented	Internal	0.5	8	4.0	Implementation Team	Project Sponsor	Mitigate	Work with business areas to map processes accurately

Components of a Risk Inventory

As a part of the RMP, agencies should document potential barriers and risks to implementation using a risk log. This section describes each component of the risk log in more detail.

Risk Identifier

This is a unique sequence number assigned to each risk identified for ease of communication and reference. For this example, the identifier "EC" plus a unique sequence number has been assigned for initial risk inventory.

Critical Success Factors

Each risk is categorized into critical success factors, which are factors that are essential to successful project implementation. Examples of success factors include, but are not limited to, executive support, allocation of resources, in-house technical expertise, proper project management, change management, and organizational acceptance.

Risk Description and Classification

The risk description designates the nature of the potential risk/barrier, and the classification defines whether the risk is internal or external.

Probability

Each risk should be assigned a probability based on the likelihood of occurrence—the higher the probability, the more likely it is that the risk will occur. The probability score should be based on a 10-point scale ranging from 0.1 to 1.0, where 0.1 indicates a very low probability and 1.0 indicates a very high probability of risk occurrence. Table 28 shows the probability distribution based by likeliness of occurrence.

Table 28. Risk probability scale.

Probability	Definition
0.1-0.2	Very unlikely that risk will occur
0.3-0.4	Unlikely that risk will occur
0.5-0.6	Equally likely whether risk will occur
0.7-0.8	Likely that risk will occur
0.9-1.0	Very likely that risk will occur

Impact

Impact measures the potential severity of the impact of the risk on the project. Impact can be rated on a scale of 1 to 10, where 1 indicates a very low impact and 10 indicates a very high impact of risk, as shown in Table 29. (Project Management Institute 2013)

Table 29. Risk impact scale.

Project Objective	Very Low 1-2	Low 3-4	Moderate 5-6	High 7-8	Very High 9-10
Cost	Insignificant cost increase	< 5% cost increase	5-10% cost increase	10.01-25% cost increase	> 25% cost increase
Schedule	Insignificant schedule slippage	< 5% schedule slippage	5-10% schedule slippage	10.01-25% schedule slippage	> 25% schedule slippage
Scope	Scope decrease barely noticeable	Minor areas of scope are affected	Major areas of scope are affected	Scope reduction unacceptable to client	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires client approval	Quality reduction unacceptable to client	Project end item is effectively unusable

Risk Score

The risk score indicates the severity of the risk, which is calculated by multiplying the probability and the impact numbers.

Figure 22 is an adaptation from the PMBOK® Guide that can be used to assess initial risk. (Project Management Institute 2013) The project risks are divided into low, moderate, and high risk based on their risk scores.

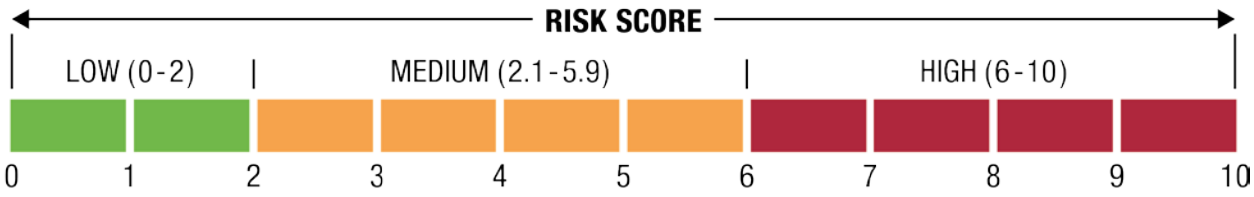

Figure 22. Scale. Calculation of risk score.

Risks with the highest scores should be the first priority in the risk response plan (part of the risk management plan), followed by moderate risks, and then by low risks.

Identified By

This attribute indicates the source that identified the risk, which can be an individual, a group, or a meeting or process used to identify the risk. For the purposes of the initial inventory of barriers and risks, "implementation team" has been used as a placeholder.

Risk Owner

This attribute indicates the individual who owns the risk. The risk owner is responsible for addressing the risk should it arise. Ownership is typically assigned to an individual, such as the project sponsor.

Risk Response

The seven potential responses to a risk are avoid, transfer, mitigate, exploit, share, enhance, or accept. Negative risks or threats should be avoided altogether, transferred to a third party, or mitigated by taking action earlier in the implementation plan rather than repairing the damaged after it has occurred. On the contrary, positive risks or opportunities should be exploited by eliminating uncertainty associated with a particular risk, shared with a third party who may be able to capture the opportunity better, or enhanced by increasing the probability for positive impacts. Lastly, accepting the risk may be a strategy that can be used for both threats and opportunities when the risk may not be eliminated. Passive acceptance requires no action, leaving the implementation team to address the risks as they occur while active acceptance requires the development of a contingency plan for known and unknown risks.

Risk Strategy and Notes

The response strategy and notes identify the strategies to respond to the risk.

Initial Inventory of Potential Risks and Barriers

The initial inventory of potential risks and barriers previously presented in Table 27 was prepared based on information gained during agency interviews and industry standards. The probability scores were assigned based on information obtained in the detailed interviews and industry best practices for technology deployment.

Change Management

Change management should happen as early as possible and continue throughout the project lifecycle. Stakeholder involvement and engagement is necessary to help manage upcoming change effectively. Since these stakeholders will ultimately become the end users of the system, it is important to ask for their feedback throughout the implementation process (and particularly during pre-implementation activities, such as business process review), keep them informed of implementation activities, involve a core group in system demonstrations, and involve users in user acceptance testing. These activities will help the agency overcome any resistance to change, ensure that the end product is a system that meets user needs, and that the system is used as it was intended once it is implemented (preventing any potential user workarounds).

Other Success Factors

Other success factors that are critical to successful implementation are described in more detail below.

Business Process Improvement

Agencies should review current business processes before implementing a new system to ensure a smooth implementation that results in a system that ultimately meets the agency's needs over the long term and minimizes any system updates that may be needed in the future. During business process review, agencies should ensure that processes reflect the agency's current practices and identify improvements that address current process and system shortcomings. Focusing on improving business processes provides a solid foundation by which future activities can build upon—well-documented processes will result in well-defined system requirements to address gaps in the agency's current systems.

Project Champion and Strong Executive Support

The implementation of any project should include a strong leader who will champion the initiative, provide support at the executive level, and who can make critical decisions and support the projects from the start. Lack of executive support can ultimately lead to failed implementation. The champion should be someone on the executive team who has the authority to delegate tasks to the implementation team and become the liaison between the implementation team and the agency executive leadership. The champion is also the person responsible for securing the funding to support the initiatives. The team should be carefully selected to ensure organizational buy-in and also the right level of expertise to advance the agency's e-Construction program.

Because e-Construction applications rely on both business processes and technology, the following team composition is recommended:

- **Executive Champion**. A member of the executive team who provides management support whose role is to be informed of the progress.

- **Team Lead**. A project manager responsible for coordinating all activities related to the scope of work and managing the overall schedule.

- **Business Process Lead**. A person with expert knowledge of the business process being affected by the application of e-Construction being deployed.

- **Technical Lead**. A person with expert knowledge of technology deployment and existing systems used in production. This member of the team is most likely already providing technical support and training of existing systems.

- **IT Liaison**. A person from the information systems group who is knowledgeable with the overall agency infrastructure, security policies, deployment requirements, and procurement of software.

- **Legal Team Liaison**. A person from the legal team with expert knowledge of the laws that guide the business process being affected by the application of e-Construction being deployed.

- **Users or stakeholders**. A diverse cross-section of multiple people who will use the systems being deployed. These people are the most affected by the implementation of new systems, thus having multiple representatives allows for feedback and staff buy-in.

Tool Selection to Support e-Construction

Agencies should understand the current capabilities of their systems before initiating implementation. They should assess current IT infrastructure, such as network connectivity, access to the internet, firewalls, storage, and databases; the types and age of computers in place for performing project delivery tasks, such as design and construction inspection; the type of software that is currently being used within project delivery and changes that may significantly impact production; funding sources; and procurement vehicles.

Software

The process for selecting the best software solution for e-Construction directly depends on agency procurement practices, the specific application, existing software and enterprise licensing agreements, and availability of COTS solutions to meet the needs. Many of these solutions are well-entrenched in the industry and may provide well-established workflows and documentation shared by most of the agencies. Nevertheless, new and more modern products have recently emerged to meet the demands of mobility in the transportation industry as well as moving digital data beyond construction. These new players are forcing the market to be more versatile and competitive, and should be considered. An RFP process through which various vendors can propose their solutions and costs can help agencies select the best software for their needs.

Hardware

Hardware to support e-Construction includes mobile devices, laptops, and surveying equipment, along with all the necessary accessories and services (e.g., impact-resistant cases, Wi-Fi, and internet connectivity). The three top considerations for choosing laptop computers and mobile devices are cost, user preference, and agency IT security policies. The considerations for

selecting surveying equipment to support the use of 3D data in the field are usually cost, software, user preference, ease of use, and quality of the equipment.

IT Platforms

There is a significant investment in setting up proper IT infrastructure and services to maintain a paperless environment. These costs include establishment or addition of digital storage through either internal Storage Area Networks and servers and/or cloud-based services, the set-up of databases to support collaboration and document management systems, and access to a high-speed communication network across the geographic jurisdiction of the agency through fiber lines and wireless (Wi-Fi) or cellular connections.

Accessibility to the records via a secure method is one of the most important items when setting up an IT infrastructure that will support e-Construction practices. Some agencies opt to keep all data stored internally on secured servers behind the firewall that can only be accessed via Virtual Private Networks or Remote Desktop connections. The advantage of using this method is that there is no need to invest in upgrading the desktop applications to offer a mobile interface. Alternatively, cloud-based technology, if set up correctly, can allow secured access via web interfaces and mobile applications from any computer or mobile device. Both methods require an internet connection for accessing records and any other data stored in the systems.

Training and Technical Support

The success of technology deployment initiatives heavily depends on the training and guidance that staff receive. Staff need training not only to learn the new software and tools, but also to understand new workflows, processes, and policies. Business and technical guidance are necessary for staff to understand the new processes that affect their daily work. Provisions, standards, and manuals will need to be updated before implementation so staff has the proper guidance to be successful. Staff who are invested in the process are more likely to welcome the adoption of a new technology or a change that impacts their everyday duties. Thus, training and technical support are key factors to achieving success.

An agency should consider different types of training programs to bring staff up to speed regarding e-Construction technologies. The training needs to accommodate many types of learners. Some employees prefer instructor-led training while others prefer a more independent style of learning. Instructor-led training can be conducted by specialized technical support staff whose primary function is to instruct. However, many agencies use the train-the-trainer approach to expand the training base from the central office support group to other geographic regions without needing to hire additional staff. Agencies should also consider just-in-time instruction, which enables staff to access training when they need it. While just-in-time training can be instructor-led when using the train-the-trainer program, it is more often used as electronic modules that include a combination of documents and videos. Because all of the improvement opportunities identified use software or an electronic tool, both the instructor-led and electronic training should also include the opportunity for hands-on practice, which can be accomplished by having sample files that the user can download and use with the software installed on the assigned computer or mobile device.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

e-Construction practices are being successfully used in many state transportation departments, and the tools for implementing these paperless environments are commercially available and supported by the industry. The use of e-Construction practices continues to grow with more awareness brought by EDC-3 efforts and federal and state research. Furthermore, e-Construction will continue to advance quickly and be supported in the fourth round of the Every Day Counts Initiative (EDC-4) to go beyond paperless practices. Thus, the recommendations for the future advancement of e-Construction here are based on the lessons learned during this study to elevate the use of digital data for project delivery to the next level.

e-Construction practices improve the efficiency in transportation agency business and quality control processes for highway construction projects. Many of the applications of e-Construction are mature within the transportation industry, and the current state of practice has demonstrated that there are benefits for both the contractor and the owner agency. e-Construction enables information to be shared quickly between all involved parties and significantly reduces or eliminates the environmental and monetary impact of printing and paper usage. e-Construction also makes historical project documents and data easily accessible, simplifies workflows, and increases collaboration both in the field and in the office. Benefits are also yielded throughout all stages of the project delivery cycle. In addition, e-Construction creates the opportunity to leverage project delivery digital data to supplement asset inventory that can be used for operation and maintenance activities.

The findings of this research and the implementation guidance presented will enable state transportation departments to expand their current e-Construction programs and use a consistent method to document and quantify benefits and calculate return on investment. The planning-level benefit cost analyses for each improvement opportunity demonstrates that agencies will yield significant savings despite the upfront investment. Agencies can use the benefit cost framework to develop a business case for e-Construction implementation or to systematically quantify benefits for e-Construction initiatives that have been implemented and in practice for several years.

The EDC-3 efforts to advance e-Construction are focused on the elimination of a paper-based electronic administration delivery process through the use of digital documents and electronic processes. Eliminating printed documents and their distribution is easily adaptable, accepted, and supported by the industry. It is also evident that the movement to a paperless environment has obvious benefits, such as reducing the carbon footprint and reducing the cost associated with paper supplies and mailing. While benefits are not easily quantifiable, many agencies have anecdotal evidence of e-Construction’s benefits and its ability to improve efficiency and transparency of the construction delivery process. The use of paperless environments has increased among state transportation departments in the last couple of years, in part due to the FHWA’s efforts to promote these technologies under EDC-3.

Another related initiative that has contributed to the adoption of e-Construction is 3D Engineered Models for Construction, which was introduced in EDC-2 and continued in EDC-3. The use of both 3D engineered models and paperless workflows have increased among state transportation departments in the last couple of years, in part due to the FHWA's efforts to promote these technologies under the EDC program. In addition, effective practices to apply these tools to construction inspection are emerging, but documentation is highly focused on specific technologies (e.g., AMG, mobile devices). Consequently, there is a gap in identifying how e-Construction and 3D data intersect. The use of 3D data, geospatial tools, and mobile technology in construction inspection is the next logical step in the evolution of e-Construction as a practice for using digital data. Further, there is a need for understanding how the digital data collected during the construction acceptance process could be integrated into asset management, operations, and maintenance practices. Electronic or digital data that is captured and managed properly can build a higher level of confidence for operating and maintaining the roadway network

This study identified the following areas for further investigation to advance e-Construction to the next level:

- Use of 3D models as contractual documents instead of electronic plan sheets.
- Use of digital data integration in construction inspection (e.g., real-time verification, measurement of quantities using surveying equipment, and low accuracy positioning for locating features).
- Use of digital data for materials management tracking and warranties that can tie to the construction management system.
- Collection of 3D as-built models and acceptance information to establish records that can be used for asset management, operations, and maintenance.
- Development of enterprise data management through governance and policy.
- Further exploration is required to identify the best mix of technology and process to meet the needs of construction inspection and administration to further improve the efficiency, safety, and use of digital records realized from e-Construction during EDC-3.

APPENDIX A: SUMMARY OF THE PHASE I COMPREHENSIVE REVIEW

PLANS, SPECIFICATIONS, AND ESTIMATES (PS&E)

PS&E practices identified during the comprehensive review include the following:

- The Northern Region of **ADOT&PF** provides 3D models of road alignments and existing ground surfaces as supplemental project information.

- **CTDOT** is using Bluebeam Revu for digital makeups and to sign digital contract plans. Staff members are able to review documents at the same time using the collaboration live review features (STUDIO) with real-time feedback.

- **DIA** has an ongoing initiative to get plans and specifications into BIM and Revit formats.

- **Iowa DOT** creates construction plans electronically and submits them to the Office of Contracts, which prepares PS&E packages and advertises them online for contractors to bid. For digital review, the agency is using Outlook to collect comments on plan sets since email allows for traceability and makes it easier to track and respond to comments.

- **MDOT** provides reference information documents during project advertisement, which supplement virtual paper and public electronic files. The agency is also exploring Bluebeam for digital mark-ups.

- **NCDOT** creates all plans in Bentley MicroStation, and these plans are then generated as PDF documents. The agency currently provides Digital Terrain Modeling for all of its projects that are let centrally. The agency also provides a 3D design file for a project if it was designed using Corridor Modeling (which is a majority of all of its projects).

- **ODOT** has been using Bentley MicroStation for 3D models for over 10 years, and effective January 2015, the agency requires delivery of digital data bidding reference packages for most roadway construction projects.

- **PennDOT** has been developing contract drawings based on a variety of parametric design software since the mid-1990s. Penn DOT has standardized on the Bentley MicroStation CADD platform and uses Bentley's InRoads as the civil design software to create 3D corridor models. These 3D corridor models are the basis for the production of contract drawings, which generate the electronic plan sheets. Although PennDOT has been sharing 3D models with contractors post-award since 2003, in January 2014, it became department policy to develop 3D models primarily, but not exclusively, for moderate to complex projects. These digital design files are shared as "For information only" reference documents with contractors during the pre-bid phase via its Engineering and Construction Management System (ECMS), an in-house developed, web-based application. Today, PennDOT shares surface and geometry files in LandXML.

- **TxDOT** is using Bentley MicroStation for 3D and 4D modeling.

- **VTrans** is using Adobe to convert files to an electronic format and review plans electronically.

ELECTRONIC BIDDING AND CONTRACTOR SELECTION

Key findings for electronic bidding practices include the following:

- **Caltrans** uses Bid Express as its primary tool for electronic bidding; however, it uses another system for contractors to download Bid Books so that the agency is able to track who is downloading documents. Contractors must log into the Caltrans website to download Bid Books for the desired project they want to bid on. While most documents are submitted electronically, some documents, such as Disadvantaged Business Enterprise forms, are still in paper format.

- **MDOT** is using boilerplate letting documents that reduce download size and reduce storage space and printing. The agency also provides reference information documents during project advertisement to give contractors access to non-contractual documents prior to bidding on construction projects.

- **PennDOT** is using its ECMS system for electronic bidding, solicitation for consultant professional services, contractor, and consultant selection, and contract execution. The system can be used to view all construction project information and documents, such as PS&E documents, contract agreements, and any other electronic documents requiring agency approval or certification.

- **TxDOT** uses a custom application, the Bid Proposal Request System, to check for the contractor's available bidding capacity. The Bid Proposal Request System takes the request from the contractor and compares the amount they are approved to bid in one application to how much the contractor has under construction with the agency in another application. The difference between those numbers is the bidding capacity.

PROJECT CONSTRUCTION MANAGEMENT

Construction Management Systems

Key findings for construction management systems include the following:

- The Northern Region of **ADOT&PF** implemented SiteManager. SiteManager was initially used to store all documents, but the database was ballooning and staff decided to store all documents in eDocs, a database that was developed internally, and provide a URL in SiteManager that would link to eDocs. Daily reports and test results are entered into SiteManager, but a lot of backup information is now stored in eDocs.

- **Caltrans** approves all contractor billings through the internet Extra Work Bill (iEWB) system, an Oracle-based system that was custom developed internally. iEWB enables verification and validation of electronic extra work bills for accuracy, which results in greater efficiency in the processing of bills. The prime contractor and the resident

engineer are able to communicate with each other when they create and send extra work bills for processing, and once the resident engineers approves payment, iEWB sends payment information to the Contract Administration System for processing.

- **DIA** is in the process of implementing Oracle Unifier to track and manage submittals, budget items, change orders, pay applications, Requests for Information, and other documents in the system. The software is cloud-based so staff will be able to access it on their phone, iPads, or other devices. In addition, the agency uses Textura for contractor pay applications. Denver International Airport implemented Textura with larger projects approximately 2 to 2.5 years ago and has now rolled it out to all projects in the past year. Contractors are able to upload information into the system, and the monthly draw, approval process, and payment release are all electronic. Contractors can go into the system and check on payment status, and they are receiving payments much faster than before. Payment time has been reduced from 30 days to 5 to 10 days.

- **FDOT** uses SiteManager on its mobile devices via the Citrix application. The agency is looking to implement AASHTOWare web-based construction management sometime by fiscal year 2017 (which means implementation began in July 2016).

- **Iowa DOT** uses Doc Express to store all contract documents, enable contractors/ suppliers to submit material certifications, handle electronic signatures, secure static payroll submittals, electronic plan room, shop drawing submittals and approvals, and change order management, including electronic signatures. All documents are kept in one place, and notifications and workflows are built into the system. As of June 2014, the use of Doc Express is required on all state-administered projects.

- **MassDOT** developed a Contract Management System (CMS) in-house (using a SQL server) as part of its Accelerated Bridge Program to manage procurement, prequalification, and some payment functions. CMS is used in conjunction with several other standalone, homegrown databases, including the Site Access Module (SAM), the District Contract Database, and the Construction Division System. The use of so many databases has resulted in data redundancy, and the agency has recognized that this has wasted a lot of valuable time. The agency is working to bring all other databases into the CMS, but this effort has been challenging and time consuming. Submittal of contractor payroll is currently a paper process. Payroll submittal information is entered into the SAM, which generates an estimate, but the agency still uses a paper process for signatures. The Comptroller's Office makes payments through the Massachusetts Accounting and Access Reporting System.

- **NHDOT** uses a Construction Management System (CMS), which was developed in-house.

- **NDDOT** uses the Construction Automated Records System, a web-based system developed in-house, to prepare pay estimates, change orders, and project records.

- **PennDOT** uses ECMS to administer a project. Since ECMS is a highly secured system based on user authentication for accessing project data, construction staff can use it to

add information to the system as project construction continues. Construction personnel add estimates, work orders, site activities, invoices, and payment information. All approvals and documentation of project site activities are completed through ECMS using automated workflows.

- **TxDOT** uses SiteManager as a construction administration tool for data collection in the field, daily work reports, contractor payments, change orders, materials tracking, and test report tracking. The Electronic Project Record System is a custom-developed software that acts as a portal to collect payroll information from contractors and to collect and track other pieces of information, such as safety reports and American Recovery and Reinvestment Act dollars. The agency is trying to move away from custom software and toward COTS software that can be supported by a vendor so it will eventually transition to using the Labor Compliance Program tracker instead. The agency is also using Primavera to manage lettings to determine how to spend funding. For construction, Primavera is used to track whether a contractor is on time and for resolution of disputes and claims.

- **VTrans** uses AASHTOWare Project SiteManager, which was implemented in the early 1990s, to handle all pay items, including change orders and pay estimates. VTrans also uses AASHTOWare Estimator for project cost estimates. Designers build their estimates for a project within Estimator, and the estimates are sent to Contract Administration electronically to use as part of project advertisement. Contractors submit their bids electronically, and this information is used to generate the electronic files that are then pushed to SiteManager. This information, including pay items, quantities, and pricing, forms the basis for using SiteManager throughout the construction phase.

Project Collaboration Tools

Key findings for project collaboration include the following:

- **DIA** has been using SharePoint as an internal reporting tool for projects. SharePoint stores the latest project information, including meeting minutes, change orders, PM plans, and stakeholder presentations. It is not meant to be a repository but rather a centralized location from which information can be easily shared so that executives on the airport team and other internal stakeholders can access certain project information in lieu of having access to the project file on the server.

- **FDOT** recently implemented ProjectSolve as its project collaboration tool.

- **MassDOT** implemented a SharePoint site for five projects for its Accelerated Bridge Program that totaled $1 billion in construction for document sharing and storing efficiency reports, non-conformance reports, photos, etc. However, since the site needs to be managed by an outside consultant, the agency is looking to transition to another platform.

- **MDOT** uses ProjectWise as the “single source of truth” for the agency in managing its contracts. The agency uses ProjectWise workflows to obtain approvals on documents

from project scoping through contract close out, including contract modifications, payrolls, and shop drawings. ProjectWise has led to increased transparency, which has subsequently led to efficiencies in the way the agency does business. The system has been in place for about 12 years. Although numerous project collaboration tools are available on the market, Michigan DOT was already using ProjectWise and had administrators who knew how to use the software since the state of Michigan has an enterprise license agreement with Bentley.

- **NCDOT** uses SharePoint to store any reports that were previously created on paper, including inspector reports and materials received reports and for collaboration between the field and the central and regional offices. Staff members in all offices are able to access and work on the same set of documents as compared to previously, when copies of the same document were sent to several different offices. SharePoint also has a search functionality that enables staff to search for documents by keyword. This has made it a lot easier for staff to find the documents they need.

- **ODOT** is in the process of implementing ProjectWise, which is scheduled for completion in 2016.

- **PennDOT** uses three systems for project collaboration, creating reports, and record storage and retention:

    - PennDOT Project Collaboration Center is a modified version of Microsoft SharePoint used for submitting documents for review. The system provides better collaboration at all levels of the agency and with business partners. It also provides more efficient access to information, true multi-user collaboration with versioning, check-in/check-out, audit trail, retention policies, the ability to add metadata, and utilization of workflows for business processes. Most importantly, this system provides construction document retention while complying with “Right-to-Know” state laws. This system is integrated with ECMS, and it is the system used to share files, photos, and training materials.

    - Electronic Document Management System (EDMS) is used for electronic archival of project documents once the project is no longer active.

    - Construction Document System (version 3) (CDSv3) was created as a companion application to ECMS for construction management and inspection of projects. The main purpose of CDSv3 is to document project site activities and contractor payments, but it also is used to create reports with data retrieved from ECMS.

- **TxDOT** is in the process of implementing ProjectWise, which is scheduled for completion in 2016. In addition, the agency uses EDMS for document management, which was implemented statewide in 2007. Although EDMS and ProjectWise serve very similar functions, the agency has set forth guidelines for which types of documents will be stored in each system. For project-specific documentation, the agency will use ProjectWise, but for internal processes such as writing manuals or internal memorandums, the agency will use EDMS. Project-specific files are stored in

ProjectWise so that files (e.g., design, construction, traffic, right-of-way, etc.) can be stored in one place for others to easily access rather than having files saved in several different places on the server.

Digital Signatures

Key findings for digital signatures include the following:

- **FDOT** uses public key infrastructure (PKI) for its digital signatures and all staff members are outfitted with IdenTrust digital certificates. Contractors must meet the minimum criteria of PKI infrastructure and National Institute of Standards and Technology (NIST) Level 3 assurance. In July 2013, Florida DOT issued a Memorandum of Understanding between the Florida DOT, the Florida Institute of Consulting Engineers, and the Florida Transportation Builders Association that established the use of e-commerce on Florida DOT construction contracts. The Memorandum of Understanding acknowledges that the delivery of construction projects is extremely complex and the use of e-commerce will help expedite the review and processing of documents and approvals.

- **MDOT** uses Adobe (since the state of Michigan already had a license for Adobe) and Form Signer by Software 602 for its digitally encrypted electronic signatures, but it is looking to transition to Bluebeam. Each office is currently validating e-signatures on its own, but the agency would like to work toward an agency-wide signature repository.

- **NCDOT** is just getting started with DocuSign for digital signatures on plans and contracts and is working on obtaining contractual agreements between DOTs and private contractors. The agency has been working with its attorneys to ensure it is proceeding legally.

- **ODOT** has an internal digital signature capacity of 2,000 and contractors must provide their own digital signatures through a third party (which costs about $10 to $15 per month per signature). Digital signatures have been widely accepted by the engineering community. In 2001, the state of Oregon adopted the Uniform Electronic Transactions Act, ORS 84.001 to 84.061, which permits the use of digital signatures, shortly after the federal law allowing digital signatures was passed. The Oregon State Board of Examiners for Engineering and Land Surveying adopted the new Oregon Administrative Rules in 2008. The agency recently developed a digital signature provision in coordination with the Department of Justice for use on two pilot e-Construction contracts. The provision states that all documents submitted to the agency for a contract that requires signatures must be signed with a digital signature that is verifiable by the agency unless otherwise allowed or directed by the Chief Engineer. The agency fully expects the provision to be accepted as a standard specification in 2016.

- **TxDOT** is pushing to execute all contracts electronically with e-signatures. The Design division rolled out DocuSign last year to sign and seal plans electronically for contract execution.

- **UDOT** has used electronic signatures for the signing and stamping of plan sets and design exceptions, as well as electronic payroll verification for over 10 years. Electronic signatures have reduced overall agency documentation and auditing costs.

PROJECT INSPECTION AND TESTING

Key findings for Project Inspection and Testing include the following:

- The Northern Region of **ADOT&PF** has mobile hot spots written into construction contracts allowing inspectors to link to cell service using a laptop so that SiteManager can be used on grade.

- **Caltrans** geo-synchronizes photos so that inspectors can access the photos on plan sheets.

- **FDOT** inputs inspection results in SiteManager. Inspection forms that need to be filled out are taken from the ProjectSolve site, filled out, and then uploaded back to the site. The agency is also developing workflows so that when forms are uploaded, a notification will be sent to the next person that needs to review it.

- **Iowa DOT** is using mobile devices to access construction documentation in the field; in addition, iPads are being used for asset management inventory and pavement management. Inspectors are using the application PDF Expert, which was easy for staff to learn and use, to view, review, and make edits/comments to electronic plan sets. PDF Expert is being used on all paperless pilot projects (and there were over 50 of these projects in 2015). When inspectors go into the field to take samples, a GPS location is snapped and added to the database to use for future decisions.

- **NCDOT** is using iPads to enable field personnel to be able to access a range of reference materials at all times, regardless of connectivity. Field personnel use Outlook for email and FaceTime to communicate with other staff. Citrix is used to communicate with the agency's financial systems, SAP, and provides access to the Highway Construction and Materials System (HiCAMS), developed in house by 1999, which is used to track all inspections, materials, and test results, as well as for contractor payments. The SharePlus application is used on the iPad to access SharePoint.

- **PennDOT** uses the Construction Document System (CDS) (which was created in-house as a companion application to ECMS) to record project activities from the diaries of the field inspector or by direct entry. The agency selected iPads for mobile inspections because of its higher level of security for accessing its other systems directly than that provided by other devices. The agency has also developed several mobile computing applications internally that are available on all PennDOT-issued iPads.

- **TxDOT** uses iPads for mobile inspection. Inspectors that do not have iPads take notes on notepads and then enter that information into SiteManager. However, the agency has received approval for a $1 million grant to distribute additional iPads in the field. The

agency may eventually transition to another tablet that supports Microsoft Office and USB ports.

PROJECT ACCEPTANCE

Key findings for Project Acceptance include the following:

- The Northern Region of **ADOT&PF** is testing Doc Express to submit documents electronically for Project Acceptance on a few contracts, although the current practice is mostly paper.

- **DIA** is using spreadsheets to track completion of punch lists, but this will change with the rollout of Unifier. In addition, BIM 360 Field is being reviewed for managing punch lists. Although a small percentage of as-built submittals from contractors are in CAD or BIM format, most of them are in paper format. As-builts from the contractor are submitted to the Designer of Record to incorporate in the final as-built that is submitted to the airport. The agency uses Maximo to track warranty items and just upgraded to version 7.5.

- **MDOT** requires a final inspection to ensure that the required documents are provided. These documents are then stored in ProjectWise. As-builts and other project information are all electronic, but some offices are more progressive than others in terms of CADD files or scanned files.

- **NCDOT** develops its own as-builts for its projects—except on design-build projects—which have traditionally been paper and then scanned. The agency is working on electronic as-builts as part of the iPad and SharePoint process.

- **PennDOT** still relies on paper-based as-built records and a combination of manual and some automated tracking of warranty items. However, PennDOT's recent upgrade to its construction management system included a mobile application to document punch lists and final inspection records.

PROJECT CLOSE-OUT

Key findings for Project Close-Out include the following:

- The Northern Region of **ADOT&PF** has some electronic close-out reports, but all close-out reports are still printed and submitted in a binder to the review team. The review team reviews the contract in SiteManager, as well as the paper copies of the reports, and the final report is printed as a PDF and is signed and uploaded to SiteManager and stored in eDocs.

- **Iowa DOT** uses the information submitted to DocExpress and FieldManager to perform audits of the item progress payments to the contractors. The "paperwork" is then submitted and processed electronically through different approval processes and Doc Express for final project close-out. This close-out process still requires manual entry into electronic systems and is not completely automated.

- **MassDOT** is planning to implement a Laboratory Information Management System. The agency would prefer to have electronic processes so that its Research and Materials Section is able to track material submittals and project close-out. The section is currently using SharePoint as a repository to store this documentation.

- **NCDOT** tracks warranties in its Highway Construction and Materials System (HiCAMS), which was developed in-house.

- **VTrans** uses Construction Contract Finals (CCF), a cloud-based business process management software, for construction close-out when field staff package all of their field records and turn them over to the Finals unit. The Finals Engineer is then responsible for checking final project quantities and paperwork, payment of final estimates to contractors once quantities have been accepted and requirements have been met, completing the extension of time process, and filing of final project records. The agency has been able to decrease its finals process from 1.5 years to about 11 months with business process management, and the CCF application will further reduce the duration of the finals process.

APPENDIX B. PRIORITIZATION ASSESSMENT

ELECTRONIC BIDDING AND CONTRACT AWARD (TABLE 30)

Description: This improvement opportunity includes bid preparation, submittal, acceptance, evaluation, and contract award through an electronic system. Electronic bidding and contract award is among the most mature of e-Construction practices; nevertheless, many state transportation departments are not maximizing the full benefits of this digital process. In many cases, the processes for preparing and evaluating bids are still manual.

Dependencies: Digital signatures.

Anticipated Benefits: Reduced paper, printing, and distribution (postage); reduced manual data entry and data redundancy; reduced time in processing bids; reduced time in posting bid results to contractors; reduced errors in bids (including calculation of price extensions and totals); and reduced incomplete bids.

Table 30. Prioritization criteria to assess implementation of electronic bidding and contract award.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, electronic bidding standardizes the bid-review process, increasing efficiency for both the contractor and the agency. Electronic bidding also ensures a smoother submittal, where contractors no longer have to rely on mailing, faxing, or bid runners to drop off bids, which is inefficient and can be unreliable. The time it takes for the agency to review bids is also significantly reduced due to automatic calculations and comparisons.	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, electronic bidding will reduce the number of hours spent for bid lettings and review freeing staff to do other tasks.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, electronic bidding enables the bid submittal information system (e.g., contract unit prices, pay items, etc.) to feed into the construction management system for project initiation without having to re-enter data. It also contributes to faster contract administration by expediting the bid-review process.	Benefit to agency

Prioritization Criteria	Evaluation	Category
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, electronic bidding reduces the risk of incomplete bids and reduces the risk of not awarding contracts to the lowest responsive bidder.	Benefit to agency
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, multiple agencies have implemented electronic bidding using COTS solutions.	Likelihood of success
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**, multiple agencies have implemented electronic bidding using COTS solutions.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**Maybe**, some state laws still require physical signatures for public projects. Nevertheless, federal law allows for digital signatures under e-Commerce statutes. Additionally, agencies may be statutorily required to provide free bidding opportunities to contractors making, which results in the state assuming all cost for mandatory electronic bidding. Agencies that have not made electronic bidding mandatory reported that most of the bids are submitted electronically by contractors anyway because of the ease and efficiency of the process, as compared to a paper process.	Likelihood of success
Is the current process complex?	**No**, a paper bidding process is not complex, but it is cumbersome because of the amount of paper documentation that must be tracked and the staff effort it takes to review all of the bids manually.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the bidding process will be significantly simplified for both contractors that are submitting bids and agencies that are reviewing bids. Electronic bidding automates calculations, which prevents math errors and has built-in checks to ensure that all blanks are filled in and all necessary forms are included. Agencies are able	Simplicity or complexity

Prioritization Criteria	Evaluation	Category
	to expedite the bid review/analysis process and reduce errors and required resources.	
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, electronic bidding can be tied to project estimation, construction management and other agency systems/tools and processes.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, most of these documents originate in an electronic form and others that are not can be converted in electronic form.	Leveraging existing resources

ELECTRONIC PLANS, SPECIFICATIONS, AND ESTIMATES (PS&E) (TABLE 31)

Description: This improvement opportunity refers to the preparation of digital and intelligent PS&E documents during the pre-construction phase including electronic specifications and estimates; and 2D or 3D digital plan sheets as PDFs generated directly from CADD software. Additionally, it includes the use of these digital intelligent documents to review, collaborate, and approve the bid package during design and advertisement. Lastly, digital PS&E documents may include issuing 3D engineered models as contractual documents during advertisement. 3D design data enables the use of quantity take-offs during bidding, the use of AMG construction methods, and quantity verification and measurements during construction. Digital PS&E documents enable other paperless processes, such as electronic bidding and digital project review.

Dependencies: Digital signatures, and 3D CADD software.

Anticipated Benefits: Reduced paper, scanning or printing costs, gained efficiencies due to faster turn-around times to receive comments during design phase, increased collaboration and transparency, reduction of change orders and claims due to better risk management.

Table 31. Prioritization criteria to assess implementation of PS&E.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, electronic plans, specifications, and estimates will allow staff to share documents quicker and improve the overall efficiency of the bidding process.	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, electronic plans, specifications, and estimates enable a more efficient review process.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, electronic plans, specifications, and estimates accelerates project delivery by reducing the time it takes to distribute paper documents to those involved in the review process.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, providing 3D models as contractual documents reassures contractors about the reliability of the quantities and communicates the design intent more accurately. Contractors use digital PS&Es to calculate bid estimates more accurately, which reduces their bidding risk which reduces the bid cost. Time savings during the estimating of the bidding quantities also allows contractors to be able to bid on	Benefit to agency

Prioritization Criteria	Evaluation	Category
	more projects, which increases competition and results in lower bids.	
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, multiple agencies have implemented electronic plans, specifications, and estimates using COTS solutions.	Likelihood of success
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**, multiple agencies have implemented electronic plans, specifications, and estimates using COTS solutions.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**Yes**, digital plans, specifications, and estimates are widely accepted.	Likelihood of success
Is the current process complex?	**No**, the process for developing electronic plans, specifications, and estimates is not complex because these documents originate in an electronic form. Advancing to the intermediate step of delivering electronic plan sheets derived from the CAD drawings is a simple process. However, making 3D engineered models the contractual documents can be a lengthy and complex process to establish depending on the maturity of the agency. Implementation of 3D design software and development of electronic deliverables can be a complex and labor intensive process. Those agencies with 3D design processes already in place will have an easier time advancing digital PS&E as contractual documents.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the bidding process will be significantly simplified for quantity calculations and communicating design intent. Additionally, having electronic PS&E documents will make collaboration much simpler. However, it is important to note that while there will be reduced paper usage and increased utilization	Simplicity or complexity

Prioritization Criteria	Evaluation	Category
	for some staff, other staff will need to focus on review digital files being delivered for the bid letting.	
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, electronic plans, specifications, and estimates can be used with the agency's electronic bidding and digital review tools.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, specifications and estimates documents originate in an electronic form. Plans are developed electronically from CADD software, so 2D data is easily converted. However, 3D data may require additional effort to identify and streamline deliverables.	Leveraging existing resources

DIGITAL REVIEW OF CONTRACT DOCUMENTS (TABLE 32)

Description: This improvement opportunity includes the review and approval of contract documents once an award has been made. The awarded contractor submits all required contractual documents via a secure electronic system for the agency to review, accept, and execute the contract before construction begins.

Dependencies: Electronic PS&Es, digital signatures, and document management system.

Anticipated Benefits: Reduced paper, printing, scanning, and distribution (postage); increased transparency, communication and collaboration; faster turnaround time for document review and approval.

Table 32. Prioritization criteria to assess implementation of digital review of contract documents.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, electronic review of documents will streamline the contract approval and execution process and allow increased transparency through reliable traceability. It reduces the need to distribute multiple copies of the contract documents to reviewers, thus streamlining the process in reducing turn-around time. Additionally, digital plan review will reduce paper usage, eliminate postage costs, and result in significant time savings from not having to deliver plans to different locations around the state. In addition, it will reduce the time for approving changes, which can keep projects on schedule.	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, the digital review process will allow staff to execute contracts faster and more efficiently from any location.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, the time savings from faster reviews and turnaround will contribute to overall faster project delivery.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, digital review of project documents will result in better traceability of required contract documents.	Benefit to agency

Prioritization Criteria	Evaluation	Category
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, multiple agencies have implemented digital review of plan sets, including the Florida, Iowa, and Vermont. These agencies have documented the qualitative benefits of the digital review process, but the quantitative benefits have not been measured/documented as extensively.	Likelihood of success
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**, digital review of contract documents can be conducted through various readily available COTS solutions.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**Yes**, digital review of contract documents is widely accepted.	Likelihood of success
Is the current process complex?	**Yes**, the manual process to review contract documents can have multiple reviewers and different workflows, making the process relatively complex. An electronic review can vastly simplify this process.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the document review process will be significantly simplified, and will have the ability to track changes electronically. Electronic records of the changes include a time stamp and the name of the person making the change. This process increases transparency and accountability.	Simplicity or complexity
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, the digital review tool can be used in conjunction with the agency's project collaboration tool and mobile devices.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, many agencies are using PDFs for review of contract documents.	Leveraging existing resources

PROJECT CONSTRUCTION MANAGEMENT (TABLE 33)

Description: This improvement opportunity refers to the use of an electronic system that handles contract administration, payroll and contractor payments review, documentation of project data and records, change order approval, project reporting, tracking of materials and daily field activities, integration of material and lab administration, and project close-out. A construction management system allows members of the project to both enter and retrieve information faster and more efficiently compared to a paper-based process.

Dependencies: Digital signatures, construction and document management systems.

Anticipated Benefits: Reduced paper, printing, scanning, and distribution (postage); reduced misfiled and lost documents; increased transparency and accountability; increased security of documents; increased access to documents; and reduced time in accessing documents.

Table 33. Prioritization criteria to assess implementation of electronic project construction management system.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, a project construction management system will address the need for consistency and standardization of processes by streamlining time-consuming processes that must go through the chain of responsibility (e.g., contractor payments).	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, a construction management system will reduce time taken to enter daily work report information, material test results, and other information. It will also reduce the time to retrieve information, thus improving staff efficiency.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, the time savings from faster information entry and retrieval will result in faster project delivery through reduced time for change order approval, faster contractor payments and other timely approval of records.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, a project construction management system will reduce overall risk, including data loss, cost overruns, etc.	Benefit to agency
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, multiple agencies have implemented a construction management system, including Alaska, Florida, Texas, and Vermont Agencies have documented the qualitative benefits of using a construction management system, but the	Likelihood of success

Prioritization Criteria	Evaluation	Category
	quantitative benefits have not been measured/documented as extensively.	
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**. There are several strong COTS solutions available in the market.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**Yes**, many existing requirements/policies support the use of a project construction management system.	Likelihood of success
Is the current process complex?	**Yes**, the construction management process is **complex** because of the multiple components that agencies need to keep track of, including people involved in the approval process, contract administration, payments, materials management, etc. This means there will be more opportunities for simplification by using an electronic system.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the current paper-based process will be significantly simplified—all documents can be electronically stored and tracked, eliminating confusion about where/how to access documents.	Simplicity or complexity
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, the construction management system can be integrated with project collaboration tools, digital signatures, and mobile devices to obtain greater benefits.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, most documents/forms originate in an electronic format or can be easily converted into an electronic format.	Leveraging existing resources

DIGITAL MANAGEMENT OF CONSTRUCTION DOCUMENTATION USING A PROJECT COLLABORATION TOOL (TABLE 34)

Description: This improvement opportunity includes the use of a document management system for sharing documents, and collaborating during the construction of a project by all parties involved.

Agencies should also consider a process to migrate documents from the project collaboration tool to an enterprise document/content management system at the end of the project (which is not considered a part of this scope).

Dependencies: Digital signatures, document management system.

Anticipated Benefits: Reduced paper, printing, scanning, and distribution (postage); increased communication and collaboration; faster turnaround time for document review; and elimination of delivery time of plans to different locations for review.

Table 34. Prioritization criteria to assess implementation of a project collaboration tool to manage digital construction documentation.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, this improvement will help standardize the way project documents are filed and stored. A standardized filing system ensures that all documents are consistently stored in the correct location (and not saved in several different places) so they are easily accessible. A project collaboration tool acts as a centralized location for all project documentation (and communication) rather than having to send copies of the same document to different offices.	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, a project collaboration tool will increase staff efficiency since documents can be accessed more quickly. It will also significantly reduce paper, mailing, and scanning costs.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, the time savings from improved efficiency will contribute to overall faster project delivery.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, it will decrease the risk of misfiling/losing documents, reduce the risk of claims/disputes, and increase overall transparency and accountability. Having a centralized location where project information is stored also makes reporting easier.	Benefit to agency

Prioritization Criteria	Evaluation	Category
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, multiple agencies have project collaboration tools, including Florida, Michigan, North Carolina, Oregon, and Texas. These agencies have documented the qualitative benefits of using a project collaboration tool, but the quantitative benefits have not been measured/documented as extensively.	Likelihood of success
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**, several COTS solutions are available.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**Yes**, many agencies have policies in place mean to allow the use of project collaboration tools.	Likelihood of success
Is the current process complex?	**Yes**, collaboration on a project can be complex due to the number of parties involved. This can be amplified if procedures are not clearly documented or if procedures are not being consistently followed. A standard electronic process can help simplify the process. In addition, the number of parties needing accessibility to the documents increases complexity.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the current paper-based process for project collaboration will be significantly simplified by having a centralized location for which all project information is stored and retrieved, thereby increasing accessibility.	Simplicity or complexity
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, the project collaboration tool can be integrated with construction management system, digital review of project documents, digital signatures, and electronic approvals.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, most of these documents originate in an electronic form and can then be stored in a project collaboration tool.	Leveraging existing resources

AUTOMATED MACHINE GUIDANCE (AMG) FOR CONSTRUCTION OPERATIONS (TABLE 35)

Description: This improvement opportunity includes the use of 3D modeling data to guide construction equipment during construction (e.g., earthwork and paving) operations.

Dependencies: 3D engineered models as contractual documents, specifications to allow AMG construction methods, and guidance for inspectors to perform quality assurance on these types of projects.

Anticipated Benefits: Increased quality management, safety improvements, real-time verification of deliverables, faster project delivery, and increased utilization of field staff.

Table 35. Prioritization criteria to assess implementation of construction methods using AMG equipment.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, with a standard specification, guidance for inspection procedures, and appropriate surveying equipment, inspectors will be able to perform quality assurance more efficiently and confidently.	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, there will be a reduction in number of inspectors needed on-site. Proper training and technical support is critical for increasing efficiencies.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, the use of AMG can lead to faster project delivery and lower overall cost, but may increase design time. AMG increases efficiency of construction activities through the reduction or elimination of survey staking, string line setup for paving, etc. However, the use of AMG is not ideal for use on every project, and is dependent on the contractor means and methods.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, when used appropriately, AMG reduces safety risk due to lower exposure to heavy equipment, reduces the risk of unnoticed errors requiring rework, and decreases overruns of material quantities.	Benefit to agency
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, many agencies are allowing contractors to use AMG construction methods. Some of those states include: California, Iowa, Michigan, Missouri, Pennsylvania, Utah, and Wisconsin. The benefits are widely recognized, but not as extensively documented.	Likelihood of success

Prioritization Criteria	Evaluation	Category
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**, but it requires staff to have knowledge of surveying principles and 3D data.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**No**, while some specifications for allowing the use AMG are available from leading states, there is limited guidance for inspectors to inspect AMG projects, thus construction manuals and training will need to be developed.	Likelihood of success
Is the current process complex?	**Yes**, the process to make digital data available to contractors to use in AMG equipment is complex for the agency, but the practice of using these construction methods is a mature approach in the contracting community. Contractors have been using AMG construction methods for grading and excavation since the early 1990's. More contractors are increasingly advancing their processes to include more complex automation.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes.** The use of AMG equipment for construction projects is a contractor's means and methods to completing the project. However, with proper equipment and guidance, construction inspectors will greatly benefit from using the same digital data the contractor uses to build the project for performing verification and quantity measurements.	Simplicity or complexity
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, automated machine guidance (AMG) uses 3D modeling data and GPS technology to guide construction equipment operators. There is also increased potential for collecting digital as-built records from the automated sensors and modern surveying equipment used during the operation.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, since 3D models originate in an electronic format.	Leveraging existing resources

REQUIREMENT OF DIGITAL AS-BUILT RECORDS (TABLE 36)

Description: This improvement opportunity refers to the requirement for providing digital as-builts in the form of 3D CADD and GIS data collected using geospatial technologies (e.g. GNSS equipment, lidar, and unmanned aircraft systems) at the time of project acceptance.

Dependencies: Digital PS&E documents, and digital signatures.

Anticipated Benefits: Reduced paper and scanning costs; having accurate and digital record of the asset conditions for potential use in augmenting programmatic asset inventory; and accessibility to reliable information for asset maintenance and operation.

Table 36. Prioritization criteria to assess implementation of requiring digital as-built records.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, data can be used for asset inventory, which reduces the need for additional collection of asset data. In addition, much of the data can be reviewed at the time of field acceptance provided the construction engineer has the proper technical expertise. Consequently, this process combines measurement of quantities and acceptance of work, and review of as-builts, which will expedite project closeout.	Benefit to agency
Will implementation improve workforce utilization?	**No**, while there will be reduced paper usage and increased utilization for some staff, other staff will need to focus on review and acceptance of digital data. This QA process requires significant technical expertise.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, digital as-built records will expedite the close-out process because the verification can happen as the work is being measured and accepted in the field, thus improving project delivery.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, accurate and well-documented as-built records ensure proper documentation of the asset condition, characteristics, and location. This ultimately reduces risk to the agency since as-built records are also an important resource for asset management.	Benefit to agency
Have other agencies implemented this improvement? Have they	**No**, some agencies have implemented the requirement for electronic plan sheets (PDF), but not digital as-built records for acceptance.	Likelihood of success

Prioritization Criteria	Evaluation	Category
documented the benefits, costs, and/or lessons learned?	The benefits for electronic plan sheets are somewhat documented. There is no documentation for digital as-built records.	
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**, there are strong COTS solutions that can be used for data collection and management of digital as-built records (e.g., GPS data collectors and mapping products). However, there are no industry standards established detailing the deliverables, thus agencies must create specifications and enforce the requirements.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**No**, specifications for allowing digital as-built delivery will need to be developed. Utah has developed specifications for at least one project.	Likelihood of success
Is the current process complex?	**No**, the as-built documentation process is relatively **simple**, but paper scanning/storing/filing is inefficient. That said, specifying the delivery of digital as-built is not common practice in the industry, and it will need coordination and collaboration with other functional units to define requirements. Additionally, the agency will need to establish a data governance plan to manage digital asset information and quality.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the process of scanning and filing paper as-built records will be eliminated.	Simplicity or complexity
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, contractors and survey crews collect data using geospatial technology (e.g., GNSS, lidar, etc.) as part of the QA/QC process. This type of information can provide features of the asset, including location coordinates (GNSS) in CADD and/or GIS data formats.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**No**, because the current creation of as-built records supports a plan-sheet based process. Agencies will need to develop new specifications to support a digital data workflow.	Leveraging existing resources

DIGITAL SIGNATURES (TABLE 37)

Description: This improvement opportunity includes the use of digital signatures for authenticating and approving documents electronically across all phases of the project delivery cycle. Digital signatures are a dependency for multiple improvement opportunities identified herein, such as accepting electronic bids, signing digital PS&E documents, managing construction documents digitally (e.g. change orders and approvals), and acceptance of digital as-builts.

Dependencies: Policy enabling the use and acceptance of digital signatures.

Anticipated Benefits: Digital signatures is a key dependency for electronic bidding as well as project collaboration, and the benefits derived are through those improvements, and not a direct result of digital signatures.

Table 37. Prioritization criteria to assess implementation of digital signatures.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, when compared to a paper signature process (which is time intensive when waiting for signatures to arrive in the mail), the use of digital signatures enables agencies to expedite the review and processing of documents and approvals, as well as the execution of agreements and change orders (e.g., it can prevent signatures from having to be validated multiple times by other offices).	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, digital signatures may relieve some staff constraints (i.e., distribution of documents requiring signatures). In many cases, staff is asked to hand-deliver documents to remote locations when signatures are required the same day.	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration, easier information sharing, etc.)?	**Yes**, the time savings from no longer having to wait for documents in the mail before they can be signed, and mailed back will contribute to overall faster project delivery.	Benefit to agency
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, digital signatures will eliminate the risk of misplaced/ misfiled documents and of losing documents in the mail; it also reduces the risk of delays in document approvals.	Benefit to agency
Have other agencies implemented this improvement? Have they	**Yes**, multiple agencies have implemented digital signatures, including Florida, Michigan, and Oregon.	Likelihood of success

Prioritization Criteria	Evaluation	Category
documented the benefits, costs, and/or lessons learned?	Agencies have documented the qualitative benefits of using digital signatures, but the quantitative benefits have not been measured/documented as extensively.	
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**. There are several COTS solutions in the market.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**It varies** by state, but many states have requirements, statutes, and/or policies that support the use of digital signatures. Electronic signatures have been incorporated as part of federal law as the "Electronic Signature in Global and National Commerce Act" and "The Uniform Electronic Transaction Act." **However**, state law may require bidding submittal to be provided at no expense to the contracting community, in which case, the agency will need to investigate different options for implementation. For example, the state may incur the cost of digital signature for all contractors, or making the use of digital signatures optional.	Likelihood of success
Is the current process complex?	**Maybe**. A paper process for approvals can be complex if there are numerous approvers involved and using digital signatures can help simplify the process significantly by eliminating the need to print and mail numerous document and enabling users to submit their signatures electronically.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, the approvals process will be significantly simplified by utilizing digital signatures.	Simplicity or complexity
Can this system/tool be used in conjunction with the agency's existing systems/tools and processes?	**Yes**, digital signatures can be incorporated into the electronic bidding process, along with all other processes that require approvals during project collaboration, project construction management, and final acceptance.	Leveraging existing resources
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, most documents/forms originate in an electronic format or can be easily converted into an electronic format.	Leveraging existing resources

USE OF MOBILE DEVICES (TABLE 38)

Description: This improvement opportunity includes the use of mobile devices to assist in both collecting and retrieving various data electronically in the field. Like digital signatures, mobile devices are used in combination with other improvement opportunities identified herein (e.g. digital access of PS&E documents, reference materials, and construction management systems).

Dependencies: There are no dependencies to implement mobile devices, but agencies would derive most benefits when using these devices as extension of other systems such as project construction management and project collaboration systems.

Anticipated Benefits: Most benefits of mobile devices are regarding faster access to information. As mentioned earlier, using mobile devices as extensions of other systems can result in an extension of benefits from other electronic systems (including improvement opportunities listed in this document). Mobile devices can also help with reduced data entry redundancy, increased data accuracy and overall quality (through automatic data validation), increased communication and collaboration using video conferencing applications, and reduced time spent traveling between office and field (thus increasing staff utilization).

Table 38. Prioritization criteria to assess implementation of mobile devices.

Prioritization Criteria	Evaluation	Category
Will implementation improve consistency and standardization/ streamlining of processes to increase overall efficiency?	**Yes**, mobile devices (and their adaptability for various uses) can help streamline various processes (e.g., inspection process) by maximizing the productive time that staff members spend in the field and increasing the efficiency of data capture and communication in the field. Mobile devices enable staff to have access to all the information they need on a single device and input data directly into the device while it is being collected (which eliminates data entry redundancy and reduces data entry errors). Mobile devices can also facilitate troubleshooting since inspectors are able to video conference with office staff from the field.	Benefit to agency
Will implementation improve workforce utilization?	**Yes**, mobile devices will increase staff utilization by reducing data entry and the need to go back to the office to retrieve data (e.g., design drawings)	Benefit to agency
Will this improvement opportunity accelerate project delivery (through improved collaboration,	**Yes**, the time savings from improved efficiency, productivity, and more timely decision making will contribute to overall faster project delivery.	Benefit to agency

Prioritization Criteria	Evaluation	Category
easier information sharing, etc.)?		
Will this reduce overall risk to the project (design rework, etc.)?	**Yes**, it will eliminate manual data entry and provide access to all project documentation (including change orders, estimates, and plans) and reduce the risk of errors.	Benefit to agency
Have other agencies implemented this improvement? Have they documented the benefits, costs, and/or lessons learned?	**Yes**, multiple agencies have implemented mobile devices. Some of those agencies are: Florida, Iowa, Michigan, North Carolina, and Texas. Some agencies have documented cost savings data from using mobile devices, and the qualitative benefits are well-documented.	Likelihood of success
Is there a strong commercial off-the-shelf (COTS) solution that can lead to this improvement?	**Yes**. There are several mobile devices available in the market, and many applications to support multiple construction management practices.	Likelihood of success
Are there existing state/federal requirements, statutes, and/or policies to support the improvement?	**Yes**, existing requirements/policies support the use of mobile devices.	Likelihood of success
Is the current process complex?	No, but this opportunity spans over multiple processes that may add a level of complexity to consider.	Simplicity or complexity
Will the current paper-based process be simplified? If so, how much?	**Yes**, mobile devices will simplify various data entry and data retrieval processes. Once the data is collected on the mobile tablet, it can be synced to the construction management system/project collaboration tool (as opposed to collecting data manually and having to enter that data later). Inspectors no longer have to carry plan sets around or travel between the project site and their trucks to access specifications and manuals.	Simplicity or complexity
Can this system/tool be used in conjunction with the	**Yes**, mobile devices can be integrated with/used as an extension to the construction management	Leveraging existing resources

Prioritization Criteria	Evaluation	Category
agency's existing systems/tools and processes?	system and project collaboration systems among others.	
Are there documents/forms that can be easily converted to/originated in an electronic format to facilitate this improvement? If so, which ones?	**Yes**, most of these documents originate in an electronic format and can be viewed on mobile devices. Mobile devices are also compatible with fillable forms.	Leveraging existing resources

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